UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)

[DESIGN AND PROTOTYPING OF WEARABLE SPINE POSTURE AND SHOULDERS CORRECTOR]

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A Dissertation Submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), University of Rwanda as partial fulfilment of the requirements for the Master's Degree in Biomedical Engineering.

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Declaration

I, **HABYARIMANA Eric**, hereby to declare that this dissertation entitled "**Design a prototype of wearable spine posture and shoulders corrector"** being submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE). University of Rwanda for the degree of MSc in Biomedical Engineering is my original work based on research and prototype and this work has not been presented for any additional academic degree or professional certification.

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Certificate

This is to confirm that the project titled "**Design a prototype of wearable spine posture and shoulders corrector**" is an original work done by HABYARIMANA Eric (220020584), a MSc. Degree student in Biomedical Engineering. This work has been submitted under the guidance of **Dr. Morufu O. Ibitoye** and **Dr. Nuhu Assuman.**

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ABSTRACT

Neck and shoulder pain are prevalent health issues, often stemming from poor posture, muscle strain, or cervical spine misalignment. This research endeavors to address these concerns through the design and development of a prototype wearable spine posture and shoulders stabilizer. The aim of this study is to create a wearable device that provides support and alignment to the cervical spine and shoulders, ultimately offering relief from discomfort, improving posture, and enhancing overall well-being. Additionally, the research incorporates the use of Transcutaneous Electrical Nerve Stimulation (TENS) as circuit system of devices. Initially, the research employed a questionnaire-based approach to investigate the factors influencing poor posture and its associated impacts. Through the utilization of cross-tabulation techniques in SPSS, the study revealed that 62% of respondents experienced both back and neck pain, while 17% reported back pain alone, another 17% reported neck pain exclusively, and 5% declared no pain. Furthermore, the research indicated that sitting position emerged as a significant contributing factor to various forms of discomfort, ultimately leading to back pain, curved necks, and related consequences. In a broader context, the study underscored the importance of wearable device design, as all respondents expressed a clear need for such devices. In summary, the Wearable Spine posture and Shoulder Stabilizer (WSPSS) proposed in this research serves as a viable solution to the challenges associated with poor posture and rounded shoulders, by limiting the movement of the spinal cord and shoulder blades; it assists in restoring an abnormal spinal cord shape. Moreover, Future directions for research and development are identified, including potential collaborations with healthcare providers and expansion into wearable healthcare technology.

Key words: Wearable devices, prototype, Spine posture, Shoulders and TENS

LIST OF ACRONYMS

CEDs: Consumer Electronic Devices

CT: Computed Tomography

EMG: Electromyography

FHP: Forward Head Posture

FHPRS: Forward Head Posture with Rounded Shoulders

LBP: Low Back Pain

MRI: Magnetic Resonance Imaging

MSDs: Musculoskeletal Disorders

NSP: Neck and Shoulder Pain

PAM: Pneumatic Artificial Muscle

SPSS: Statistical Package for Social Science

TENS: Transcutaneous Electrical Nerve Stimulation

VDT: Visual Display Terminal

WCSSS: Wearable Cervical Spine and Shoulder Stabilizer

WSPSC: Wearable Spine Posture and Shoulders Corrector

WMSDs: Work-related musculoskeletal disorders

WULD: Work-Related Upper Limb Disorders

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CHAPTER 1. GENERAL INTRODUCTION

1.1 Introduction

Neck and shoulder pain are pervasive health concerns that affect millions of people worldwide[1]. These discomforts often arise from various factors, including poor posture, extended periods of sedentary work, and musculoskeletal conditions. However, Long times of computer use, with a stationary body position have already been linked to neck and upper-limb illnesses [2]. So far, Poor posture can significantly diminish the quality of life by causing chronic discomfort, musculoskeletal problems, and reduced mobility, often leading to persistent pain, limited physical activity, and an overall sense of physical unease[3]. Approximately a third of individuals utilizing a visual display terminal experience discomfort in the back and neck [2], [4]. It is worth noting that neck pain represents a smaller portion of work-related musculoskeletal disorders compared to back pain. Nevertheless, neck pain is often a subject of study, particularly in the context of sedentary job roles that involve extensive computer usage [4].

Historically, the world has been technologically transformed and nowadays many people are staying long hours in from of the computers or hunching over cell telephones[5]. Bending while sitting and standing causes the extra strain stressed on muscles. Continuous isometric contraction consequently diminishes the blood flow to the muscles, which could result in discomfort and pain. To overcome those developed challenge, a wearable technology has emerged as a promising avenue for improving health and well-being, by correcting awkward positioning and poor posture[6].

Globally, more than $100 billion per year projected to be spent directly and indirectly for spinal treatment posture correction. However, 80% of the world population suffer from back pain due to bad posture and spinal excessive movement [7]. In Japan, there is a diverse population of individuals aged 65 and older, which comprises roughly 31 million people, constituting about 25% of the total population. With the swift progression toward an aging society, the demand for skilled caregivers has surged significantly. Reports indicate that a substantial 70% of nurses require assistance with managing back pain. Consequently, there is an urgent requirement for the advancement of both wearable and non-wearable lifting assistive devices within the healthcare sector[8]. Because of the rapid advancements in consumer electronics, a wide array of portable consumer electronic devices (CEDs) has significantly altered the lifestyles of individuals. These

CEDs offer convenient services for tasks like messaging, video calls, entertainment, and even business communications. Electronic payments have become widespread in numerous regions and countries, to the extent that, in some instances, people find it challenging to function efficiently without CEDs. Nevertheless, the unhealthy body postures adopted by individuals while using CEDs have adverse effects on their well-being, potentially leading to the impairment of normal bodily functions [2].

The alignment of human body parts, such as the head, neck, and back, holds significant importance for their overall health and functionality. Poor postures of these body segments can subject them to excessive forces[9]. Research has explored alterations in muscle engagement associated with changes in neck and trunk posture angles during smartphone usage. The findings revealed that, shortly after commencing smartphone use, there was an increase in flexion in the neck and trunk. Furthermore, it was observed that smartphone use could lead to shifts in muscle activation patterns, potentially resulting in muscle discomfort [9]. In a separate study conducted by Straker et al. in 2011, it was emphasized that the habitual seated posture adopted while using a computer was strongly linked to the occurrence of neck and shoulder pain[10].

In the sagittal plane, incorrect postures often involve the head being positioned forward and the body adopting a bent and relaxed stance[11]. Those postures are commonly assumed by computer users as they require minimal muscular effort but impose greater strain on the passive Para-spinal structures [12]. Specifically, the forward elevation of the head, which combines lower cervical flexion and upper cervical extension with rounded shoulders, may result in a weakening of the cervical extensor muscles and an increase in compressive forces at the spinal joints. Previous research has indicated a positive correlation between the activation of the upper trapezius muscle and the flexion of the cervical spine during computer use[13], [14].

Hence, various domains within biomechanics, ergonomics, and biomedical engineering have deliberated on the concept of an optimal seated position to prevent poor posture [15]. Generally, this "ideal" seated posture is described as a neutral spine position, which implies a slight lumbar curvature and a relaxed chest along with a neutral cervical spine [16]. While achieving and sustaining such an ideal posture can be challenging, and there are doubts about its practical feasibility in everyday life, recent research conducted by Sullivan et al. (2018) indicated that there were no significant disparities between the clinically determined ideal posture and the posture that individuals subjectively considered as idea[17] .

Various ergonomic studies have emphasized that not only devices but also evaluation tools and interventions can be employed to modify and retrain posture[18], [19]. The majority of ergonomic research related to seating primarily focuses on the type of chair and the orientation of the backrest, assessing their influence on body movement and muscle engagement. These devices are believed to contribute to achieving proper postural alignment, subsequently reducing sustained muscle strain. However, they can potentially limit spinal mobility, posing a risk for poor sitting habit[20]. Furthermore, recent research has suggested that ergonomic adjustments may not consistently provide long-term relief from low back and neck discomfort [21]. Biofeedback has been recognized as an effective intervention for posture retraining and reducing the excessive activation of the upper trapezius muscles[22].

The Wearable Spine Posture and Shoulders Stabilizer (WSPSS) is a medical device used as a quirky poor posture corrector and rounded shoulders by using materials that restrict the movement of the trapezius muscle and scapula, and to help rebuild the ligaments of the spine with the assistance of electrodes for electrical nerve stimulation. Most frequently, sagittal plane views of the head or neck posture are used in clinical and research contexts to quantify neck posture in two dimensions[23].

TENS Transcutaneous Electrical Nerve Stimulation) is widely employed in developed countries, particularly in Western nations, as a means to alleviate various types of pain, including both acute and chronic noncancerous pain as well as pain stemming from cancer and its treatment[24]. I is an affordable, non-invasive, and safe technique with minimal side effects. The Wearable Spine Posture and Shoulders Corrector (WSPSS) incorporates TENS therapy, which utilizes low-voltage electrical currents to alleviate pain. A TENS device typically comprises a battery-operated apparatus that transmits these electrical impulses through electrodes placed on the skin's surface[25]. In general, numerous studies have proposed that the forward head posture (FHP), frequently adopted by office workers, involves a combination of lower cervical flexion, upper cervical extension, and rounded shoulders[26], [27].

The main objective of this research project is to design a prototype wearable cervical spine and shoulders stabilizer. This device is intended to offer support and alignment for the cervical spine and shoulders, ultimately mitigating neck and shoulder pain, improving posture, and enhancing the overall quality of life for its users. Additionally, the outcomes of this research endeavor are expected to provide researchers with valuable insights into the postural alignment of the cervical and shoulder regions within a distinct age demographic. These findings can contribute to the assessment of the correlation between neck and shoulder discomfort and overall body posture. Furthermore, the results hold the potential to enhance the treatment and care of individuals experiencing neck pain. Moreover, this study serves as an inspiration for forthcoming researchers in this domain, urging them to embrace a comprehensive approach that spans multiple stages, encompassing design, prototyping, analysis, testing, and validation.

Finally, this study also outlined the factor influencing bad posture and its impact to the people. Finally, this research also provide an alternative solution for poor posture problems by taking into account activities of designing a prototype of wearable cervical for neck and shoulder stabilization so as to help huge number of people to regain a normal curve of spine.

1.2 Problem statement

Neck and shoulder pain are pervasive health concerns that affect millions of people worldwide[1]. Poor posture is increasingly prevalent due to modern lifestyles that involve prolonged sitting, excessive use of computers and smartphones, and reduced physical activity. The ubiquity of this problem underscores the need for a solution[28]. Young people spend more time playing video games and inappropriate social media, resulting in poor posture and round shoulders, and affecting the spine with upper back pain, neck pain, head injury, spinal disc and arm pain, which is a big problem for the future Generation (Figure 1.1)[29].

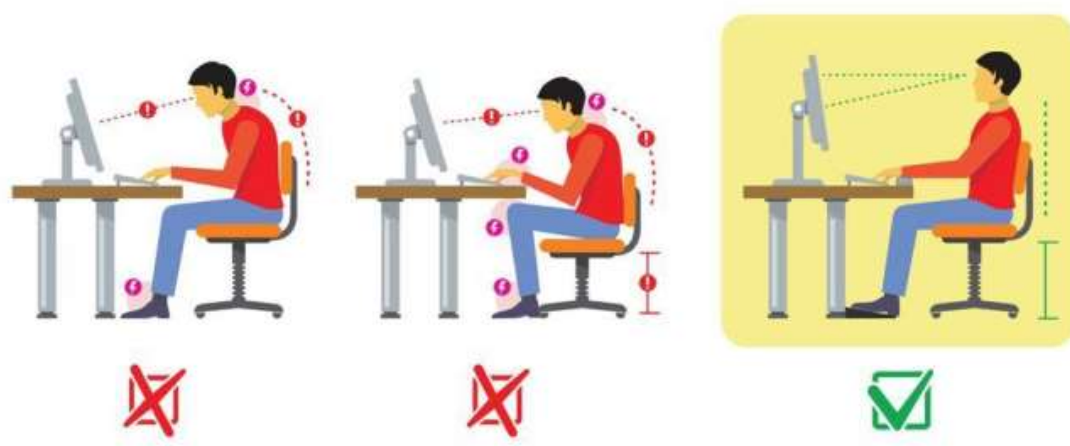

Figure 1.1: Bad posture effects the whole body.

Many individuals are unaware of their poor posture until they experience discomfort or pain. A lack of education and awareness about the importance of good posture contributes to the problem, which may lead to musculoskeletal disorders, including chronic back pain, reduced mobility, and increased susceptibility to injuries.

NSP is a prevalent health issue experienced by both the general population and individuals in the workforce. According to Machino *et al* in 2021, most people (two-thirds of adults) attacked with neck pain throughout their lives [30]. And some authors identify (NSP) as a major contemporary health problem affecting tens of millions of workers worldwide each year [31].

Correcting poor posture is a complex challenge, as it requires sustained behavioral changes. Wearable devices must not only provide immediate feedback and support but also encourage users to maintain proper posture over time[32]. Maintaining proper posture ensures the alignment of the spinal vertebrae, while adopting poor posture has been associated with diminished health and decreased performance. Inadequate postural habits can lead to the contraction of chest muscles, resulting in excessive rounding of the upper back or chest, as illustrated in Figure 1.2 [29]. Consequently, the muscles in the upper back tend to lose their tone and eventually weaken. The research gap for the "Design and Prototyping of Wearable Spine Posture and Shoulders Corrector" study lies in the need for a comprehensive, customizable, user-friendly, technologically advanced, evidence-based, and cost-effective solution that effectively addresses posture correction and its long-term effects. By addressing these gaps, the study aims to contribute to the development of wearable devices that can improve posture and overall musculoskeletal health for a wider population. Poor posture can significantly diminish the quality of life by causing chronic discomfort, musculoskeletal problems, and reduced mobility, often leading to persistent pain, limited physical activity, and an overall sense of physical unease[3]. Therefore, we are introducing a wearable cervical spine and shoulder stabilizer designed to enhance well-being by offering the necessary support to sustain good posture and promote bodily mobility.

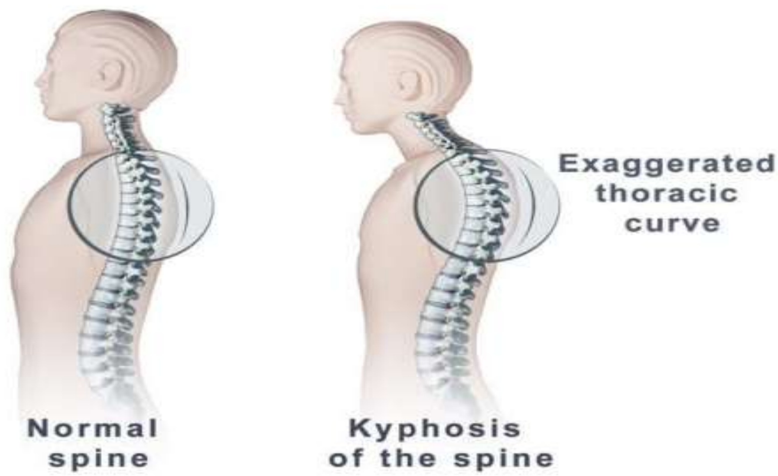

Figure 1.2. Normal curve versus kyphosis of the spine

1.3 Research Questions

The research question that emerged is: "What are the prerequisites and procedures involved in developing a prototype for the stabilization of the neck and shoulders?" This central question prompts the investigation of specific queries aimed at elucidating the essential components of this study:

1. How do socio-demographic characteristics influence the history of back pain among participants?
2. What is the frequency of workstation adjustments used by participants to prevent back pain and discomfort?
3. What are the participants' perceptions regarding the factors that affect spinal posture at work?
4. How can the optimal location for TENS electrode placement be identified to achieve maximum muscle contraction in wearable spine devices?

1.4 Objectives

1.4.1 General Objective

This project aimed to design a prototype of wearable spine posture and shoulder stabilizer to help the people with bad posture and rounded shoulders to regain normal curve and prevent bad posture.

1.4.2 Specific Objectives

To attain the general objective of this project, precisely, the subsequent objectives are used as guiding points:

1. To determine the history of back pain according to socio-demographic characteristics of the participants
2. To determine the frequency of work station adjustments used to prevent back pain and discomfort
3. To determine the perception of the participants regarding factors affecting spinal posture at work
4. To integrate the TENS electrode placement for maximum muscles contraction through identification of the optimal location in wearable spine.

1.5 Study Scope

The scope of this study, focused on the "Design and Prototyping of Wearable Spine Posture and Shoulders Corrector," encompasses a comprehensive investigation into the development of a wearable device aimed at correcting poor posture and rounded shoulders. This research involves the design and prototyping of an innovative corrective system that specifically targets the cervical spine and shoulders, addressing issues arising from modern sedentary lifestyles and technological habits. The study delves into factors influencing poor posture, the health implications of musculoskeletal discomfort, and the integration of technology, including TENS, to aid in the quick recovery of pinched nerves. Additionally, the research employs surveys and data analysis techniques to understand user needs, preferences, and the impact of poor posture. Ultimately, the study aims to contribute a wearable solution that promotes better posture and musculoskeletal health, enhancing the overall quality of life for individuals experiencing posture-related discomfort.

1.6 Significance of the Study

1.6.1 General and Social significance

Wearable devices designed to improve spinal posture prove effective in gently guiding the shoulders into the correct alignment, stabilizing both the spine and shoulders, thus preventing slouching, a leading cause of back and neck discomfort. In addition, Posture correctors are wearable aids designed to help users sit or stand up straight[33]. They can promote postural awareness and train muscles to maintain a healthy posture. Furthermore, it will increase or maintain physical health of users.

1.6.1 Economic significance

Wearable technology serves various purposes, such as monitoring health and fitness, managing chronic illnesses, engaging in interactive gaming, tracking performance, and navigating locations. It will also save money spent for example on medical expenses like checkups, treatments of people suffering from back, and neck pain and associated factors.

1.7 Organization of the thesis

This thesis comprises five chapters. Chapter 1 provides an introduction to the topic, offering a brief overview of the background, outlining the problem statement, and establishing the study's objectives.

Chapter 2 serves as a comprehensive literature review, aiming to present an overview of prototype designs globally that address the issue of correcting poor posture. This chapter is crucial in identifying pertinent studies upon which to base the development of an appropriate portable cervical design for stabilizing the neck and shoulders. To achieve the objectives of this study, various sources, including journal articles, online materials, conference papers, and books, were accessed and utilized as research materials.

In Chapter 3, the materials and methods employed in the study are elaborated upon. This chapter outlines the criteria and procedures essential for prototype design, providing a detailed flowchart that illustrates the design process.

The Chapter 4 presents and discusses the research results on design the prototype of wearable cervical spine and shoulder stabilizer to help the people with bad posture and rounded shoulders to regain normal curve and prevent bad posture has been pinpointed and discussed in the literature.

This thesis ends with the conclusions and recommendations in Chapter 5, where all findings summarized and some recommendations proposed to future researchers for improving the significance of the current study outcomes.

1.8 Summary

In the chapter of general introduction of the study, we can learn that at present, due to the rapid and accelerated advance of society, science, technology and culture all over the world, it poses big challenge to human beings to maintain a long-term and healthy body. Among them, the risk of cervical spondylosis is increasing rapidly in people's daily life.

The rapid aging worldwide has increased the scale of people suffering from neck diseases and back pain. Now there are about 100 million people suffering from neck and pain. This scale has ranked fourth in the world disease ranking, and has the trend to become the third. With the advance of science, technology and urbanization, society have changed from extensive physical and industrial labor to lighter office work, which makes people sit for 8-10 hours a day for a long time. People are forced to keep sitting in the same seat, the same posture and the same time every day.

It is important thing to learn that there is a correlation between neck, back and shoulder pain with the advancement of technology like computers and cell telephone. This results in the adoption of poor posture. Therefore, it is found to be the problem of protecting spine health.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

In this part, the focus is directed towards prior research endeavors that bear relevance to the current study, which is centered on the creation of a prototype for correcting poor posture. The aim here is to investigate and draw upon pertinent insights from previous studies, thereby narrowing existing gaps within the academic literature, research methodologies, and earlier findings. This process serves to align and integrate prior knowledge with the present study. Additionally, it contributes to an enhanced comprehension of the current research, encompassing both theoretical and empirical literature. The chapter not only offers a comprehensive summary of research instances pertaining to this design but also conducts an in-depth analysis of their principal concepts, merits, demerits, and their overall contribution to the current design. Topics covered include the correlation between prolonged seated posture and instances of neck pain and occupational neck discomfort, the utilization of artificial muscle-driven wearable devices, and the incorporation of medical equipment for rectifying poor sitting posture, as well as the utilization of existing commercial products in the development of wearable devices.

2.2. Definition of key terms

a) **Posture**

Body posture refers to the specific arrangement and alignment of an individual's body parts at any given moment, reflecting how they position themselves in relation to the effects of gravity. It encompasses the way we hold ourselves while sitting, standing, lying down, or engaging in various activities. Body posture is not static but dynamic, as it adapts to different tasks and movements. Proper body posture is characterized by the optimal alignment of body segments, reducing stress on muscles, joints, and tissues, while allowing for efficient movement and minimizing the risk of discomfort, pain, or injury. Conversely, poor body posture involves suboptimal positioning of body parts, often resulting in muscle tightness, imbalance, and increased pressure on musculoskeletal structures, which can lead to various health issues over time[34]-[34].

b) **Spine cord**

The spinal cord is a vital component of the central nervous system, serving as a cylindrical bundle of nerve fibers that extends from the base of the brain, down through the vertebral column (Figure 2.1). It functions as a communication highway, transmitting signals between the brain and the other of the body. The spinal cord plays a crucial role in relaying sensory information, such as touch, pain, and temperature, to the brain for processing, and it sends motor signals from the brain to initiate movements and actions. It also supports reflex actions, which are rapid, involuntary responses to stimuli that don't require conscious thought. Overall, the spinal cord is indispensable for the coordination of bodily functions and is integral to our ability to sense and interact with the external world.

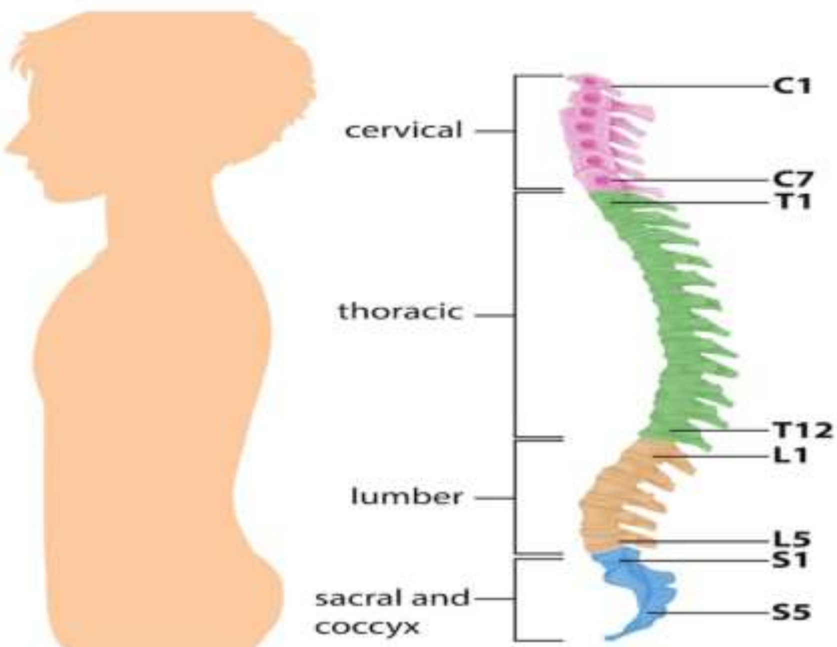

Figure 2.1. Spine cord

c) **Wearable technology**

Wearable technology, often referred to as wearables, encompasses a diverse range of electronic devices and accessories intended to be worn on or integrated into the human body. These devices typically incorporate advanced sensors, microprocessors, and connectivity features that enable them to collect, process, and transmit data. Wearable technology serves various purposes, from tracking health and fitness metrics like heart rate and step count to providing real-time notifications, augmented reality experiences, and hands-free communication. These devices are designed to seamlessly integrate into the user's daily life, offering convenience, accessibility, and personalized data insights[32].

2.3 Neck and shoulder pain

NSP is a common discomfort experienced in the upper body region, typically characterized by varying degrees of soreness, stiffness, or sharp sensations. It frequently arises due to a blend of factors, including inadequate posture, muscle tightness, excessive use, physical injury, or preexisting medical conditions. This type of pain can manifest as localized discomfort in the neck, shoulder area, or radiate into adjacent regions, potentially leading to headaches, restricted mobility, and diminished overall quality of life. Neck and shoulder pain It can manifest as either acute, which implies a brief duration of symptoms, or chronic, indicating a prolonged presence of discomfort. Proper evaluation and treatment are essential to relieve symptoms and tackle the root causes, particularly in cases of chronic discomfort[28].

Discomfort in the back and neck, as well as headaches, and pain in the shoulders and arms, are frequently associated with computer usage. These issues often arise or worsen due to inadequate desk ergonomics, suboptimal posture, and extended periods of sitting[35]. While sitting demands less muscular exertion compared to standing, it still leads to physical weariness and necessitates maintaining certain body parts in a static position for extended durations[32].

Cervical alignment is deemed suboptimal when the head and torso are positioned in a forward manner related to the lumbo-pelvic part[36]. Stretching the spine results in heightened engagement of the cervical erector spine, trapezius, and thoracic erector spine muscles[37]. There is supporting evidence suggesting a connection between maintaining a prolonged forward-flexed posture of the trunk and an elevated risk of experiencing upper body symptoms, primarily due to heightened muscle strain[38].

Neck and shoulder pain comprises various conditions, with some having clear medical definitions, while others pose greater challenges in terms of diagnosis[39]. Severe and damaging conditions, like displacements, ruptures, spinal cord disorder, pathogens, vessel ailments, systemic irritating disorders, and tumors, can lead to neck and shoulder pain. The most prevalent forms of neck and shoulder pain encompass a variety of issues, such as muscle, tendon, joint, and nerve disorders. However, the specific causes may differ, leading to unclear diagnoses, and often, similar symptoms. In some instances, there may be limited associations between symptoms and the presumed underlying causes of disability[40].

Furthermore, discomfort experienced in the neck and shoulder part can be interconnected with overall bodily discomfort affecting various areas. In terms of its origins, these issues are frequently linked to psychological stress, somatization, and functional limitations. [41].

In a static study conducted by the Herman Miller Group, a group of 40 office employees was observed over a total of 160 hours. The findings revealed that a significant 93% of these workers spent their time in a seated position. This highlights the prevailing sedentary nature of office work, which can contribute to the development of suboptimal posture. This, in turn, can result in a range of health issues, including abdominal discomfort, as well as pain in the back, neck, and shoulders. Additionally, it can lead to conditions such as spinal cord injuries, circulatory problems, and musculoskeletal complications, including spondylitis and discomfort in the neck and lower back[42].

2.4 Morphology of neck and shoulder

- **Neck**

The human Cervical backbone, comprising seven vertebrae, five intervertebral discs, and 37 distinct joints, accompanied by an array of muscles and ligaments, represents an intricate and relatively more agile yet less stable section of the spinal column[43]. Neighboring vertebrae are connected through soft tissue components, specifically intervertebral discs, ligaments, and muscles. The human cervical backbone can be categorized into two structural segments: rigid and pliable tissues. The rigid components encompass the vertebrae and intervertebral discs, primarily serving as load-bearing structures to withstand compressive forces. In contrast, the pliable elements, which consist of muscles and ligaments, play a pivotal role in stabilizing the neck and facilitating head movements. While individual joints within the spinal column exhibit limited mobility, the neck as a whole can flex, extend, rotate, and tilt, encompassing a relatively extensive range of motion[44].

- **Shoulder**

It seems to offer a foundation for the upper extremity within the shoulder area[45]. The shoulder comprises three main bones: the collarbone, known as the clavicle, the shoulder blade, or scapula, and shoulder joint. The collarbone attaches to the body at the sternoclavicular joint and forms a connection with the shoulder blade at the acromioclavicular joint. Unlike the clavicle, the shoulder blade lacks a direct assembly of its own and relies on muscles for support and stability[45]. Figures 2.2 and 2.5 show two views of neck/ shoulder region [46].

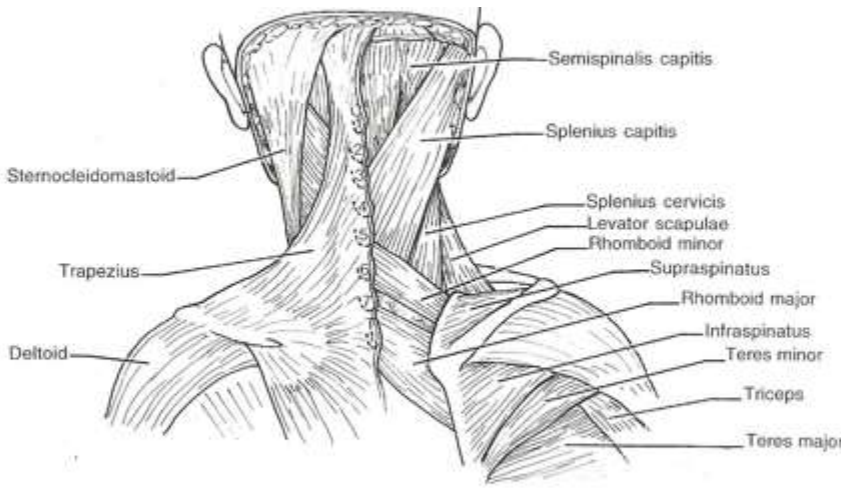

Figure 2.2. A rear view displaying the superficial muscles of the cervical spine and shoulders

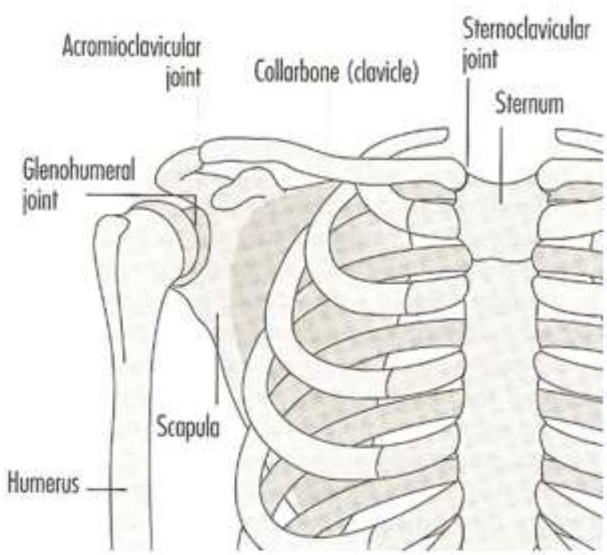

Figure 2.3. A diagram illustrating the bony structures in the shoulder area

2.5 Risk factor influencing NSP

The trajectory of NSP can be described as sporadic, occurring at different phases in an individual's life, with varying degrees of improvement between episodes. Multiple factors, encompassing diverse aspects, play a role in shaping this journey, spanning from the initial onset of symptoms to the process of recuperation or relapse, and even the requirement for medical intervention. These risk factors can exhibit variations at each stage of the NSP experience. For instance, specific research findings suggest that the demographic and work-related factors contributing to the development of skeletal-muscle discomfort differ from those influencing the need for sick leave and the utilization of healthcare services for musculoskeletal issues[47]. Numerous studies of this nature specify that job-related physical factors are more strongly linked to the need for sick leave due to neck pain than to the initial happening of these symptoms[48], [49].

Conversely, other research highlights the importance of demographic elements and, to a lesser extent, work-related social-emotional factors as contributing factors to the need for sick leave[49]. In general terms, the existing evidence regarding risk factors for NSP is of restricted quality owing to the diverse approaches used in measurement [49], [50]. However, a recent thorough examination of risk factors linked to neck and shoulder pain (NSP) indicates the presence of varying degrees of evidence strength [24], [51], [52]. Different risk factor is discussed below.

2.5.1 General sociodemographic factor

- **Age**

Outcomes from investigations into musculoskeletal disorders (MSDs) reveal an association between age and the prevalence of MSDs across various occupational categories, such as nurses[53]. There is a commonly held belief that the aging process is correlated with musculoskeletal problems, involving, and physiological changes such as declining physical capabilities and diminished cardiovascular; and skeletomuscular capacity. Age is also intertwined with the number of years individuals have dedicated to their respective professions, which exposes them to potential risk factors for extended periods. However, it's important to note that specific studies have indicated that musculoskeletal disorders, injuries, accidents, illnesses, and absenteeism tend to be more common among younger workers[43].

- **Gender**

Women have a more likelihood of experiencing NSP compared to men [54], and there is a slightly greater prevalence of symptoms in women compared to men across various age groups. One possible reason for this pattern is that, on average, women tend to possess less muscle mass and strength compared to men. Researchers have considered gender as a potential factor in several studies examining its impact on the increase of overall health issue and skeletal muscle disorders, while taking into account various occupational and non-occupational influences[55].

- **Education**

The educational level can deed as an indicator for various other elements, including socioeconomic status, job position, or way of life[56]. Education can directly impact health-related behaviors, as individuals who achieve high levels of education during childhood are more likely to adopt healthier habits in adulthood, particularly in relation to dietary choices, smoking habits, and physical activity[57]. Recent research findings propose that a lower level of education is associated to a greater occurrence of back pain[58].

- **Job title (occupation)**

Previous studies illustrate that individuals in various professions frequently experience a heightened commonness of NSP[59]. In a research conducted by Ostergre and colleagues in Sweden, male laborers exhibited a greater likelihood of emerging persistent neck discomfort when compared to their male counterparts in executive or professional roles[54].

- **Body Mass Index and anthropometric measures**

Some studies have suggested a link between a rise in BMI and a heightened likelihood of experiencing neck discomfort[60], [61], although other research has not corroborated this connection[62].

2.5.2 Lifestyle factor

- **Physical activity**

The relationship between physical activity and neck and shoulder pain remains somewhat uncertain[59]. Additional long-term studies indicate that engaging in regular exercise or physical activity did not influence the occurrence of neck pain[63], [64]. Hildebrandt and colleagues presented contradictory findings concerning the impact of exercise on neck and shoulder pain and its potential for enhancing recovery from such discomfort[65].

2.5.3 Individual physical and psychological factors

- **Physical factors**

Research suggests a connection between exercise capacity and neck pain: Individuals with low to moderate static force in their neck muscles are more likely to experience neck pain [96]. The occurrence of consistent or persistent neck pain increases by 21% and 31%, respectively, in workers who perform poorly to moderately on a neck/shoulder isokinetic lifting test[65].

Psychological factors

Psychosomatic factors of risk have a significant impact on NSP and seem to have a significant influence on the shift from acute to chronic pain. These factors are commonly explored in the literature as cognitive, emotional, and behavioral elements, encompassing aspects like pain beliefs, coping techniques, as well as levels of anxiety and depression[66].

2.5.4 Physical work factors

The connection between workplace physical factors and musculoskeletal disorders, including NSP, has garnered differing levels of confirmation for a cause-and-effect relationship across diverse epidemiological investigations. Nonetheless, numerous factors contribute to the intricacies of examining these associations, risk elements, and resulting consequences. These complexities include the absence of a universally recognized measurement tool for assessing this link, leading to the utilization of diverse approaches, both subjective and objective, for this purpose. Furthermore, these various physical risk factors frequently co-occur, making it challenging to isolate their individual effects. Additionally, the interaction between these risk factors can have a synergistic impact[64].

- **Prolonged sitting work**

Recent research has identified a connection between extended periods of sitting and the occurrence of neck pain. The static nature of this exposure appears to be a plausible mechanism driving this association, as prolonged sitting imposes a continuous static strain on the muscles of the neck[67].

- **Neck posture**

Prior studies indicated a potential connection between an office worker's neck rotation and the presence of neck/shoulder symptoms. However, this relationship did not reach statistical significance in multivariate analyses based on observed exposure data[68]. Conversely, analyses of self-reported data demonstrated noteworthy associations between neck extension and neck/shoulder symptoms. Interestingly, neck flexion did not exhibit an association with these symptoms. Another study examining neck symptoms did not identify statistically significant links with observed neck rotation. Nevertheless, it did detect a tendency toward an association between neck flexion and neck symptoms[69].

- **Awkward posture**

Uncomfortable positioning has been linked to a heightened likelihood of neck discomfort across various professions, including carpentry, office work, machine operation, and employment in nursing homes[51].

- **Heavy physical work**

Numerous studies have provided evidence for the connection between physically demanding work and the occurrence of neck pain[70], [71]. Heavy workloads, uncomfortable postures, repetitive motions, and exposure to vibrations, either individually or in combination, have been identified as significant risk factors for shoulder ailments[72]. An investigation conducted within a population-based study found that tasks involving lifting heavy loads, assuming uncomfortable positions, exposure to vibrations, and repetitive work all heightened the risk of developing a clinical shoulder disorder, with long-lasting effects[73]. Additionally, it was observed that predictors for shoulder disorders varied between men and women in this study [73]. Another study by the same research group uncovered distinctions in the causes of nonspecific and specific shoulder pain.

2.5.5 Physical factors at work

The development of NSP cannot be solely attributed to physical working conditions, as suggested by existing evidence. Psychosocial factors are likely to play a significant role in the occurrence of NSP, and they are particularly relevant in the progression from acute to chronic issues[74]. he term "psychosocial factors" encompasses a wide array of elements that become apparent when examining the workplace environment from psychological and sociological viewpoints. This includes psychological, organizational, and social aspects of the work environment. The diagram below illustrates the potential interconnections between psychosocial and physical risk factors, personal factors, and NSP, as adapted from previous research.

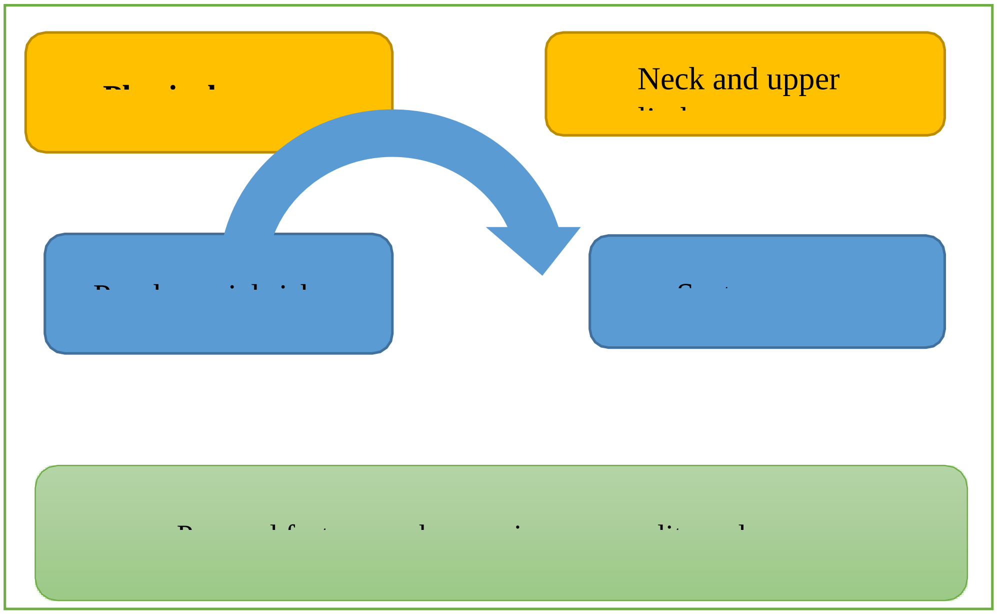

Figure 2.4: The potential linkages among psychosocial and physical risk factors, personal variables, and NSP are being explored

2.6 Theory behind the mechanism of risk factors

Physical and psychosocial factors have been associated with NSP through different mechanisms and pathways, including theories like the Cinderella theory, the hyperventilation theory, the migraine theory, and the muscle spindle theory[74], [75].

2.7 Risk factors and protective factors

Numerous studies have provided evidence that various risk factors can significantly affect cervical health[76]. In addition to gender, age, and a history of injuries, one of the most influential factors is the duration of sitting in daily life. A systematic review article focused on cervical pain has examined the primary risk factors as well as protective factors. It has identified physical, psychosocial, and individual risk factors. Moreover, measures aimed at preventing risk factors can play a role in reducing or alleviating the risks associated with them[5].

2.8 Musculoskeletal disorders and neck/shoulder pain in middle and low-income countries

Although industrialized countries often have a relatively well-established regulatory framework and infrastructure to address workplace health and safety issues, there is a significant amount of illness concealed in low- and middle-income countries due to inadequate data collection systems, and the working populations in these poorer nations tend to suffer from higher levels of overall ill-health that often goes unreported[77]. Workers' health and safety are not prioritized in these countries, particularly in the unorganized sector.

Workers' health and safety are typically not given priority in these countries, particularly in the informal sector. Limited information is available on musculoskeletal disorders (MSDs) in low- and middle-income countries, except for regions like Europe, North America, and a handful of high-income countries such as Japan and Australia. Most studies conducted in these countries are descriptive, cross-sectional, and conducted in local languages. Overall, while some published papers offer insights into the prevalence and potential patterns of MSDs in a few low- and middle-income countries, they do not provide a comprehensive understanding of the impact of neck and shoulder pain (NSP) on individuals or society as a whole[78]. Additionally, there is a lack of information on the trends in MSDs in low- and middle-income countries[79]. Table 2.1 provides an overview of the occurrence of NSP in middle- and low-income countries as investigated by various researchers.

Table 2.1: Occurrence of NSP in middle- and low-income countries

Author(s) year	**Country**	**Subjects - Number**	**Outcome measurement**	**Occurrence**
Adedoyin, R et al 2005 [80]	Ngeria	Computer users in federal universities n=1041	Questionnaire	Point occurrence Neck pain: 73% Shoulder pain: 63%
(Chopra et al 2017) [81]	India	Bhigwan village >15 years n=4092	Door to door interviews	One week pain prevalence: 6%
Hsin-Yi LEE et al 2005 [30]	Taiwan	Countrywide study for general workforce (y1998) n=17669	Survey (some part originated from Nordic questionnaire)	The one-year prevalence of neck symptoms is 24.5%, while shoulder symptoms are reported at 26.9%. Among those experiencing neck issues, 14.8% sought medical treatment, and for individuals with shoulder problems, 16.6% sought medical treatment.

(Smith et al., 2004) [82]	China	Female recorded nurses n=282	Consistent Nordic survey	One year occurrence of Neck pain: 45% Shoulder pain: 40%

2.9 Overview on wearable technology

While it is widely acknowledged that improving posture through ergonomic solutions like adjustable chairs or workstation modifications can prevent work-related spinal disorders and back pain, there is a scarcity of reliable and accurate methods for continuously monitoring posture across various situations[83]. Consequently, there has been a growing interest in wearable sensing technologies designed for posture monitoring, offering the flexibility to monitor posture anywhere and anytime. Researchers in this field are striving to incorporate wearable computing devices and sensors into textiles for data collection[84]. However, it's important to note that the integration of sensors into a comprehensive system, as well as factors like comfort, aesthetics, and wearability, are often overlooked in this context.

Prior research can be categorized into three distinct groups based on the measurement methods employed. The first category involves the utilization of fiber optic sensors, where the intensity of light passing through the sensor serves as the measurement tool, directly proportional to the degree of sensor bending[85]. Fiber optic sensors have also been applied to assess seated spinal posture in previous studies[86]. albeit with limitations in capturing only specific postures involving backward bending. The second group of research utilizes non-intrusive pressure sensors. For instance, Dunne et al. in 2005 utilized textile piezoresistive pressure sensors to monitor shoulder and neck movements by detecting pressure changes between the skin and the textile[87]. However, there has been no examination of how these devices respond to movements of varying magnitudes. The third category of research explores the use of accelerometers, as demonstrated by Jianting et al. in 2015, where accelerometers were employed to measure joint angles, yielding accurate results[88].

2.9 Wearable devices with pneumatic artificial muscle

During the 1950s, Dr. Joseph L. McKibben, a U.S. physician, developed a pneumatic component designed to facilitate the movement of prosthetic devices to assist patients in their rehabilitation process. McKibben pneumatic artificial muscle (PAM) is another name for this invention. Many remarkable benefits of pneumatic artificial muscle include high compliance, softness and lightness, high strength, high explosive power, safety, simple material, and low cost. As a result, it has been studied and applied in a variety of fields for many years[89].

2.9.1 Composition and control of artificial muscle

The usual pneumatic artificial muscle setup is quite straightforward. It's made up of a fiber interwove pipe wrapped around a rubber inflatable pipe. A pneumatic device provides airflow to the other side of the pipe while one side is closed. By applying air pressure to the inflatable rubber pipe, the overall structure will stretch by expanding longitudinally and contracting axially. The strength of the shrinkage force and the degree of shrinkage of the overall mechanism are determined by the air pressure of the inflation device, the material strength, and the overall structure size, such as the width of the rubber inflation pipe. Since the intensity and extent of contraction are fixed, the controller can primarily control the overall structure through airflow control, which is typically controlled by valves[90].

2.9.2 Softness and wearability of artificial muscle

The substance made of artificial muscle is primarily composed of rubber and fiber, which have softness and lightness properties. As a result, it is widely used in wearable devices. Medical products and robotics are the most common. It can be used to make prosthetics in the medical field. Lower body prosthetics can help paraplegic patients walk again. It can also be made into small devices at the same time. It is used to replace active control of the human body in very small structures, such as hand structures and even organs, in order to achieve contraction function. It has numerous application scenarios as well as potential research value[5].

2.10 Proposed good method of sitting

Numerous studies have proposed optimal sitting postures, one of which is the Forward Head Posture (FHP). It has been identified as a prevalent postural deviation, affecting approximately 66% of the patient population by conservative estimates. This atypical posture is believed to be associated with the onset and persistence of various conditions, including cervicogenic and migraine headaches, myofascial pain syndrome, irregular scapular movement, and even temporomandibular disorders[39].

(Won et al., 2015) determined that distinct head positions exert varying influences on head/shoulder movement and muscle engagement. Their discoveries substantiate the clinical belief that alterations in posture linked to a Forward Head Posture with Rounded Shoulders (FHPRS) can modify scapular movement and muscle activation in individuals exhibiting this posture [91]. Conversely, another study suggested that FHP results in rounded shoulders and neck discomfort due to an imbalance between spinal curvature and neck muscle attachment[92].

2.10.1 Pain Management in developing countries

While there is a scarcity of epidemiological data, the International Association for the Study of Pain (IASP) posits that "the prevalence of various pain types may be substantially higher in developing nations than in developed ones," encompassing regions like Africa and the Middle East[93]. Contributing factors include limited resources, a lack of knowledge among healthcare professionals, and a shortage of pain specialists. This has led to significant implications for pharmacological treatments, as many medications commonly used in developed countries have become inaccessible to the public due to economic fragility and the limited purchasing power of citizens[36]. Moreover, even when medications are accessible, they may be counterfeit, adulterated, expired, or compromised due to inadequate storage conditions.

2.11 Existing designed of wearable devices

Different researcher has been designed various wearable devices as described in the table 2.2. And it was adopted from[94].

Table 2.2: The indicate the existence of different wearable devices designed by different researchers

REFERENCE	EXISTING DEVICES	EXISTING DEVICES	DEVICE TYPE
(Bell J, 2007) [95]	Fiber-Optic Goniometer system	Fiber Optic Sensor.	Wearable Sensor System
(Charry E, 2011) [96]	Dorsavi' Vimove	IMU Sensors (One Tri-Axial Accelerometer, One Single Axis Gyroscope)	Wearable Sensor System
(Dunne L, 2008;2(2)) [85]	Plastic Fiber Optic System	Optical Fiber Sensor	Wearable Sensor System

(Gleadhill S, 2016; 49 [97]	Spine Angler	Inertial Sensor	Wearable Sensor System
(Kang S, 2017; 17(2560) [9]	Intelligent Clothing	IMU Sensors	Wearable Sensor System
(Leung K, 2012) [98]	Limber	Inertial, IMU Sensors	Wearable Sensor System
(Nath N, 2017; 62	Portable Sensors with IMU	Mobile Sensors, Inertial Sensors	Wearable Sensor System
(Plamondon A, 2007; 38 [24]	Mixed System	Inertial Sensors	Wearable Sensor System
(Sardini, 2019) [99]	Proximity Sensor	Proximity Sensor	Wearable Sensor System
(Tsuchiya Y, 2015 [100]	Flexion Sensor, Inertial	Inertial Sensors, Flex Sensors	Wearable Sensor System
(Yan X, 2017; 74 [101]	Yei 3-Space	IMU Sensors	Wearable Sensor System

2.12 Epidemiological background and social impact of cervical pain

Cervical pain is becoming more common all over the world, and it has the characteristics of being long-term, chronic, and recurring. The onset, recovery, and repetition of cervical pain is a very common process over a person's lifetime. Cervical pain is distributed as follows, based on some common risk factors: According to existing research, the incidence of cervical pain in one year ranges between 10.4% and 21.3%. According to Misailidou et al., 2010, a regular review of cervical pain, the global incidence rate of neck pain in the 878 articles is 16.2% [102]. Kim et al., 2018, Office and computer workers are more prevalent. Women's occurrence is generally higher in developed countries than in developing countries, and it is higher in cities than in rural areas [103].

More than 5 billion people global experienced lower spine pain in 2015, and more than 1 billion experienced neck pain for more than 3 months. Cervical pain has risen to fourth place in the world. For many years, lower spine pain and neck pain have been the main causes of infirmity in most nations and age assemblages. The study also found that lower spine and neck pain commonness and infirmity have amplified over the last 25 years. According to this study, the malignant impact of neck pain on human health is likely to be more serious as a result of urbanization and aging, as well as recent international events and scientific and technological development[1].

2.12.1 Relationship between sitting posture and cervical spondylosis

One of the important hazard factors for neck pain and cervical diseases is the quality and duration of sitting posture. In addition to proving the correlation, it also involves professional habits and specific posture of the human body to maintain sitting posture, such as arm height, back tilt angle, human activity space limitation, and so on[103]. There are numerous causes of human neck pain and cervical diseases, but the primary hazard factors can be separated into three categories: physical factors, psychological factors, and personal factors. Personal factors such as gender, age, injury history, and psychological factors should be eliminated. In terms of physical risk factors. Sitting posture duration. In addition, the sitting posture is too long. Both demonstrated a strong risk correlation[104].

Generally, people who must frequently sit in front of a computer to study or work are most likely attacked by cervical spondylosis. Although dynamic sitting posture is critical for maintaining back muscle health. Unfortunately, workers who devote a lot of period in front of computers usually adopt a few different sitting postures. Mild and chronic pain will not change people's sitting posture in healthy people, which is very unfavorable for disease detection and prevention. Sitting posture can be measured for 24 hours by placing a pressure sensor on the seat and obtaining data on sitting posture[105].

Therefore, monitoring and feedback on sitting posture can significantly improve people's awareness of sitting posture. Nevertheless, it is impossible to distinguish the causes and consequences of sedentary behavior and disease in people who have developed neck pain or back muscle group injury. It is most likely a vicious circle with mutually reinforcing relationships [105].

Also, a study found that when using a smartphone while sitting, the flexion angles of the cervical spine segments vertebrae in the neck pain group were expressively higher than those in the control group at (P 0.05) and 0.1001[40]. Therefore, Sitting with a smartphone appears to be more likely than standing to cause variations in the angle of the head and neck. As a consequence, the extensive use of smart phones today is likely to a neck muscle and back pain as well as rounded shoulder [106]. Also study findings proved that people could not rely on nature and consciousness to effectively correct their posture and spine shape[106]. The Figure 2.5 indicate spine position in 3D.

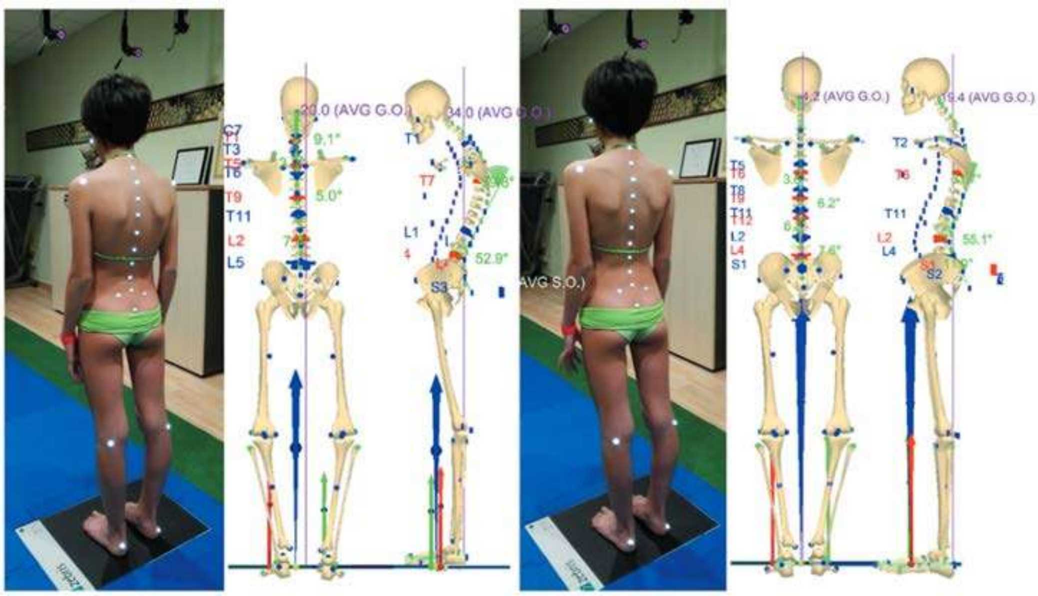

Figure 2.5: Estimating spine position through 3D image recognition

2.12.2 Research on artificial muscle and wearable devices

The actual human muscle group may be simulated by combining multiple artificial muscles, connecting them in series, and accurately controlling each artificial muscle. Each artificial muscle can be controlled in relation of human actions, such as walking and upper limb interaction [107], [108]. Small artificial muscles are wounded and rotated into special glove that controlled by a program to achieve detailed control of hand extension bending and rotation. Furthermore, while aerosol artificial muscle uses compressed air as its power source, its pressure is low, allowing for the miniaturization of artificial muscle. In such miniaturized wearable devices, artificial muscles have obvious advantages[109].

Through research and understanding of relevant fields, artificial muscle has the advantages of flexibility and strength as the main power source to provide contraction force, which differs from the hard and immovable correction device used to fix bones in medicine. Thus, expectations of a human body correction by a prototype of a wearing device are met by artificial muscle. Simultaneously, the wearable correction device is able to sense human posture via the sensor, analyze, and judge body adjustment through program. To some extent, the wearable device powered by artificial muscle can alleviate the problem of human discomfort and boredom initiated by shock reminder devices[110].

2.13 Summary

According to the second chapter of state of art and related studies, it is undeniable that long-term sitting in front of computer while working are a strongly correlated to the adoption of bad posture and consequently lead to a risk factor for cervical illness which result to neck and back muscle group pain. It is not difficult to find in the literature review that researchers from various fields have proposed a variety of solutions to the problem of better regulating people to maintain good sitting. However, some studies propose wearable devices that can help to correct poor sitting posture and claim that they have a benefits of portability, strength, and low cost. These benefits play a significant role in the amplification of human-wearable devices. Furthermore, it will provide people with a comfortable and standardized sitting experience if combined with intelligent control and soft wearability of artificial muscles.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research setting

A research setting refers to the physical, social, or conceptual environment in which a research study is conducted. The research setting plays a crucial role in shaping the study's methodology, the selection of participants or subjects, and the generalizability of research findings, as it influences the context in which data is gathered and analyzed, thereby influencing the study's validity and relevance to real-world situations. The preliminary investigation conducted in the Kigali area using designed questionnaire, specifically focusing on permanent office workers and university students, laid the foundation for the current study. By examining the factors and impacts of long-term sitting in both office and classroom environments, this preliminary investigation served as the genesis or starting point for the research of **DESIGNING AND PROTOTYPING OF WEARABLE SPINE POSTURE AND SHOULDERS CORRECTOR.** It likely involved activities such as gathering initial data, identifying potential research questions, assessing the relevance of the study to the target population, and potentially uncovering trends or issues related to prolonged sitting habits in these settings

3.2 Study design

The study on "Designing and Prototyping of Wearable Spine Posture and Shoulders Corrector" likely follows an exploratory and experimental design. In the exploratory phase, researchers might conduct a comprehensive review of existing posture correction devices and related literature to inform the design process. Subsequently, an experimental design could involve the creation of multiple prototypes, each with varying design elements and materials. These prototypes may be tested on a sample of individuals to assess their comfort, effectiveness in posture correction, and user-friendliness.

3.3 Study population and sampling

This study focused on the people who are in a working condition that might be at risk of developing back and neck pain like officer workers and Students were considered because they can sit for long period in front of computers sometimes without changing the position.

The sample size is an important aspect for study whose main goal is to draw conclusions of a whole population from a sample and the sample size (*n*) required depends on the acceptable error and P-value threshold[111].

In the current study, respondent sampling were chosen based on regular interval sampling techniques at a certainty level of 84% with 0.7 degrees of inconsistency and a 10% of the margin of error as a level of accuracy while using the following formula[111] as illustrated in the following Equation (1).

$$n = \frac{Z^2\hat{p}\hat{q}}{e^2} n = \frac{Z^2\hat{p}\hat{q}}{e^2} = \frac{(1.42)^2(0.70)(0.30)(1.42)^2(0.70)(0.30)}{(0.10)^2 \quad (0.10)^2} = 42 \text{ participants}$$

Equation 1

where:

n is represent sample size; $\hat{p}\hat{p}$ is estimated proportion of people who satisfied with the desired characteristics. (in this study, $\hat{p}\hat{p}$ is the percentage of peaple who are theoretical to to understand the significance of wearable device design. Therefore: $\hat{p}\ \hat{p}$= 50% and $\hat{q}\hat{q}$ = 1-$\hat{p}\hat{p}$ = 50%); e is the tolerable margin of error; Z represents the statistical value obtained from the standard normal distribution table corresponding to the selected confidence level, while α is a researcher's chosen value used to assess the statistical significance of random sampling. It reflects the researcher's acceptable probability of a Type I error[112].

Primarily, this research were collected data related poor sitting position that may cause to back and neck pain.

3.4 Data collection instrument

The questionnaire was formulated based the problem statement in order investigate the need of designing a prototyping of device that can help people who might at risk of poor posture through different questions. It was programmed using micro soft form, after the entire link was shared to the respondents and after sending their responses, were downloaded as excel format.

3.5 data analysis

The answer sheet were imported in (Statistical Package for Social Science (SPSS), for further analysis for intendance frequency of response and percentage.

3.6 System requirement and design

Analysis and concise reading are performed to identify the various components that can be used by the system to function properly, including hardware, software, and other relevant materials. In addition, documentation on system activities such as input, processing, and output were conducted for designing a prototype of wearable devices. More broadly, as part of the initial study, system requirements analysis seeks to identify system-specific problems and needs [113].

Design a prototype of Wearable spine posture and shoulders corrector (WSPSC), we need a SOLDWORKS 3D CAD software for designing an upper back shape and print it out. Plastic upper back shape helps to regain the normal spine curve by limiting the movement of upper back muscles.

Creating a model in SolidWorks typically commences with a 2D sketch. This sketch comprises various elements like points, lines, arcs, conics, and splines. Dimensions are incorporated into the sketch to specify the dimensions and positions of these elements. Relations are employed to describe characteristics like tangency, parallelism, perpendicularity, and concentricity. SolidWorks operates in a parametric manner, which means that the geometry is influenced by the dimensions and relations, rather than the reverse. These sketch dimensions can be managed independently or can be linked to other parameters within or outside of the sketch. Figure 3.1

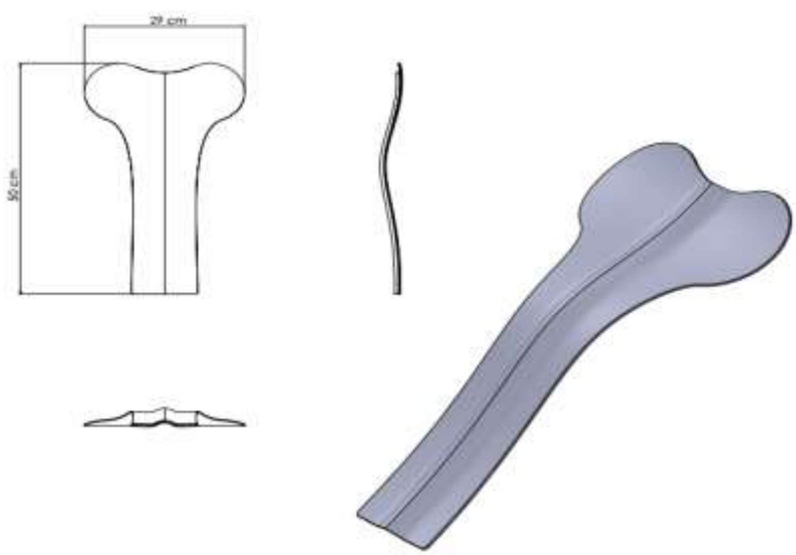

Figure 3.1 Plastic upper back shape

Among materials suitable for 3D printing, resin possesses restricted flexibility and strength. It is composed of liquid polymer that solidifies when exposed to UV light. Resin primarily comes in black, white, and transparent options, although some 3D-printed objects have been created using orange, red, blue, and green varieties. The material comes in the following three categories:

- **High-resolution resins**: Typically employed for crafting small-scale models demanding intricate details. For instance, four-inch figurines featuring intricate clothing and facial features are frequently 3D printed using this type of resin.
- **Paint-friendly resin**: Occasionally utilized for creating smooth-surface 3D prints, resins in this category are renowned for their visual appeal. Figurines featuring finely detailed facial features, like fairies, are commonly crafted from paint-friendly resin.
- **Transparent resin**: This represents the most durable resin category, making it well-suited for a variety of 3D-printed items. It is often chosen for models requiring a smoother tactile feel and a transparent appearance**.**

Figure 3.2 3D Printer machine

We employ a specific type of paintable resin to produce the upper back shape. Paintable resins are known for their robust mechanical properties, making them exceptionally suitable for the most challenging applications. They exhibit resilience against stress, as well as the ability to endure shocks and impacts, all while remaining intact and free from fractures or breakage.

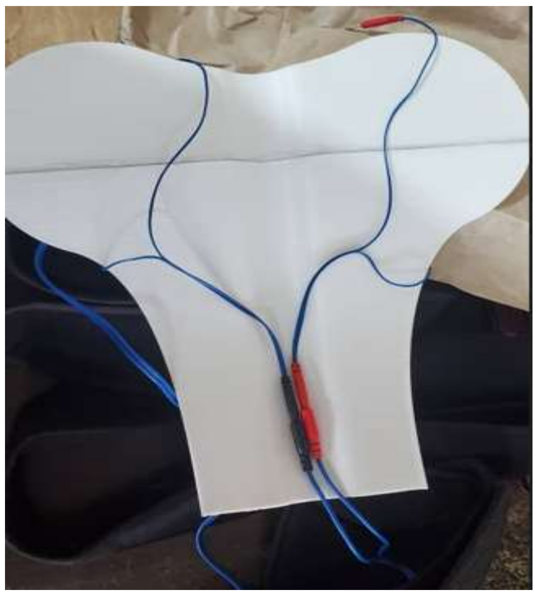

Figure 3.3. TENS Wires incorporate on plastic back shape

Transcutaneous electrical nerve stimulation (TENS) is a treatment method employing a low-voltage electrical current to alleviate pain. A TENS setup comprises a device powered by a battery, which emits electrical pulses through electrodes positioned on the outer layer of your skin. These electrodes are strategically placed either directly on the nerves causing the pain or in proximity to trigger points.

Figure 3.4 TENS Machine and Pad on skin

The electrical signals generated by the TENS Machine can diminish the pain signals traveling to the spinal cord and brain, potentially leading to pain relief and muscle relaxation. Additionally, they might promote the release of endorphins, the body's innate pain-relieving substance.

Figure 3.5. Inner side of WSPSC with electrodes pads

3.6.1 Flowchart of the design

At the large-scale application of prototype of wearable devices for monitoring body posture, the genesis of current study is to design a prototype of wearable devices that can help people with pad posture to regain the normal shape and stabilize the shoulder by using, the figure3.12: indicate the step by step of the design.

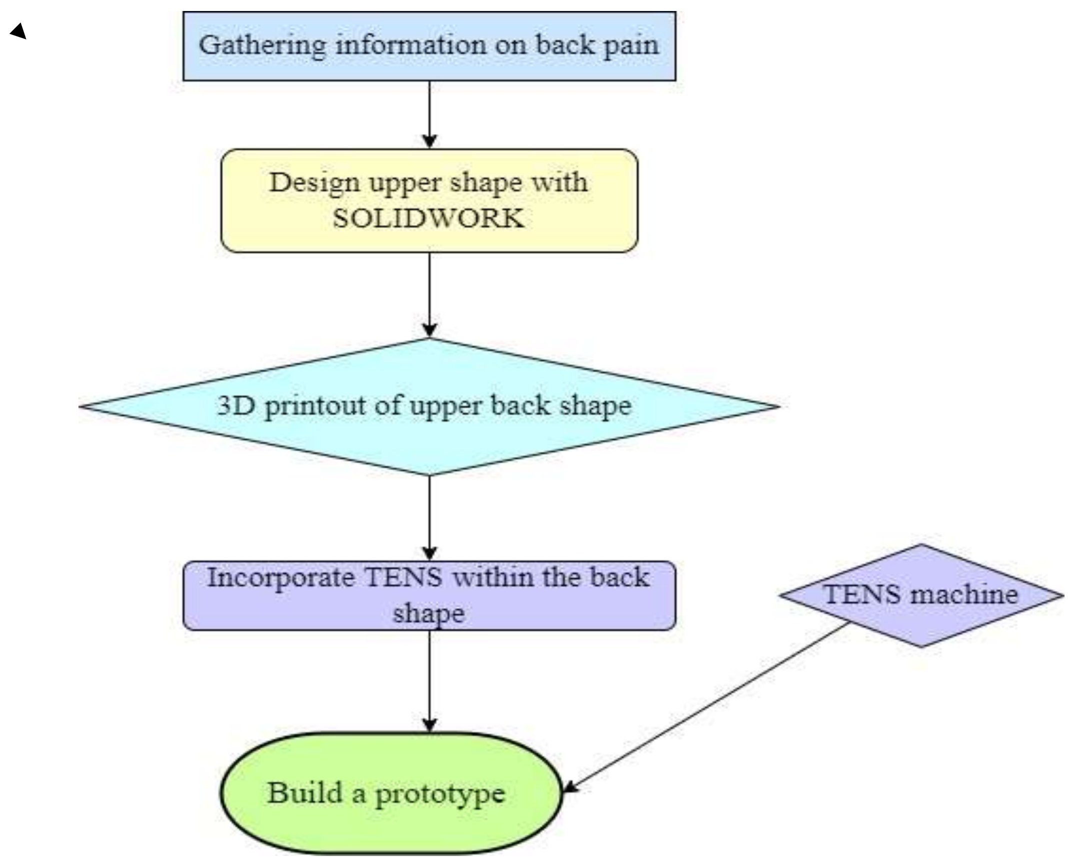

Figure 3.6: Schematic process of the prototype design

3.6 Summary

This chapter describe the methods used during the research work, material used as well as to accomplish the objective of this research, which state that design the prototype of wearable that can help people with bad posture to regain the normal shape of cervical spine. Based on the different methods related to the current study. I plan to use solid works, incorporated with TENS as circuit functionality. Furthermore, it provides the step by step for which have followed in order to get final product.

CHAPTER 4. THE PROJECT RESULTS

4.1 Quantitative results

Quantitative results, often derived from numerical data, provide a quantitative assessment of a particular phenomenon, allowing for precise measurement and analysis. These results are typically expressed in numerical values, percentages, or statistical parameters like means, standard deviations, and correlations. Quantitative research aims to quantify relationships, differences, or patterns within a dataset, enabling researchers to draw objective and statistically significant conclusions as shown in Table 4.1.

Table 4.1. Quantitative results of varous respondent characteristics as analyzed using SPSS (n = 42).

Variables	**frequency**	**Variables**	**Frequency**
1. Gender		**6. Pain occurrence**	
Man	23(54.8%)	No	4(9.5%)
Women	19(45.2%)	Yes	38(90.5%)
2. Age of respondent		**7. Pain feeling**	
Between 31-50	20(47.6%)	Back pain	8(19%)
Above 50	5(11.9%)	Neck pain	7(16%)
Less than 30	17(40.5%)	All above	27(64%)
3. Respondents occupation		8. How often do you adjust your sitting position	
Manager	4(9.5%)	10-20 minutes	4(9.5%)
Skilled worker	6(144.3%)	21-30 minutes	5(11.9%)
Students	12(28.6)	31-40 minutes	18(42.9%)
Officer worker	19(45.2%)	Above 40 minutes	15(35.7)
Unskilled worker	1(2.4)	9. Need of wearable device	
4. Working experience		Yes	42(%)
Between 6 -15 years	28(66.7%)	No	0(%)
Less than 5 Years	10(23.8%)	10. If yes how often should it help?	
More 16 years	4(9.5%)	Low	3(7.1%)
5. Back injury occurrence		Medium	12(28.6%)
No	34(81%)	High	19(45.2%)
Yes	8(19%)	very high	8(19%)
5. Back injury occurrence			
No	34(81%)		
Yes	8(19%)		

The Table 4.1 indicate the summary of questionnaire results by indicating the number of respondents chosen certain answer with percentages obtained using SPSS.

The results in the table above are consistent with the information obtained in the literature to investigate if it the same in the field:

1. Most people are isolated from home to study and work longer, and almost all of them sit in front of the computers.
2. Most respondents think they cannot often adjust sitting posture while working and almost all say they have the experience of back and neck pain after working for a long time
3. Also this study intend to know to what extant does wearable devices is required, Most respondents are considered that it is most crucial for helping in maintaining good posture.

4.2 Respondent perceptions on the causes and impact of poor posture

In Figure 4.1 and Figure 4.2, respondents were inquired to ascertain the major causes and impacts of poor posture to assess the severity of back and neck pain as well as spine.

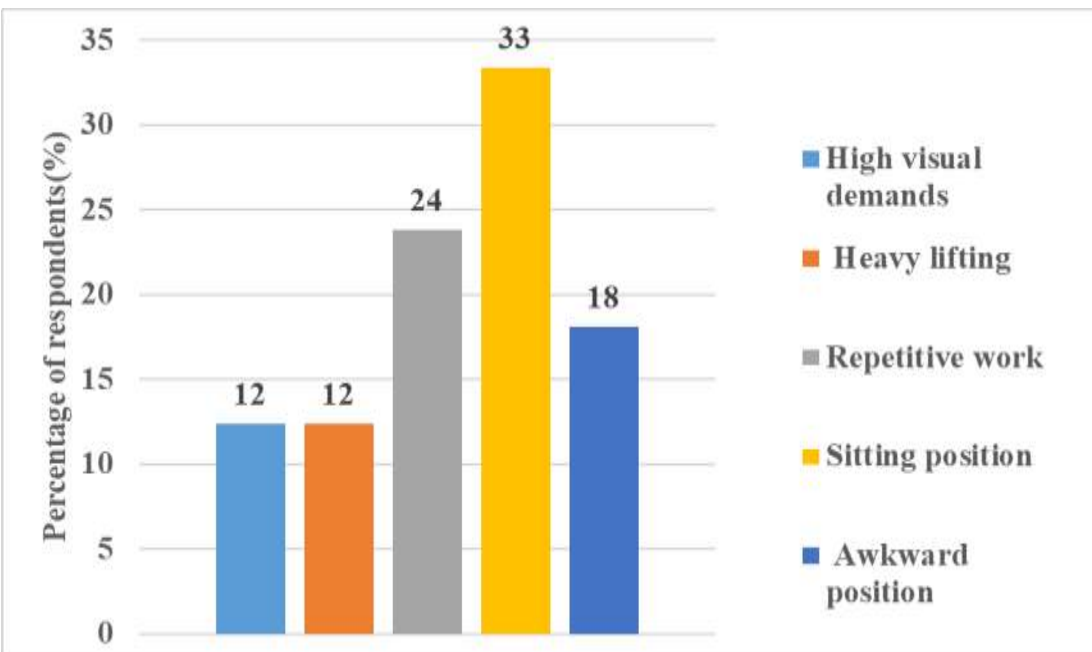

Figure 4.1: Factor that influence poor body posture

Various factor of poor posture given in Figure 4.9. indicate that, interviewed respondent indicate that the most factor influence poor body posture is sitting position, repetitive work and awkward position with percentage of 33% , 24% and 18% respectively. Many studies has confirmed that sitting position is the main causes of poor body posture [72], [73].

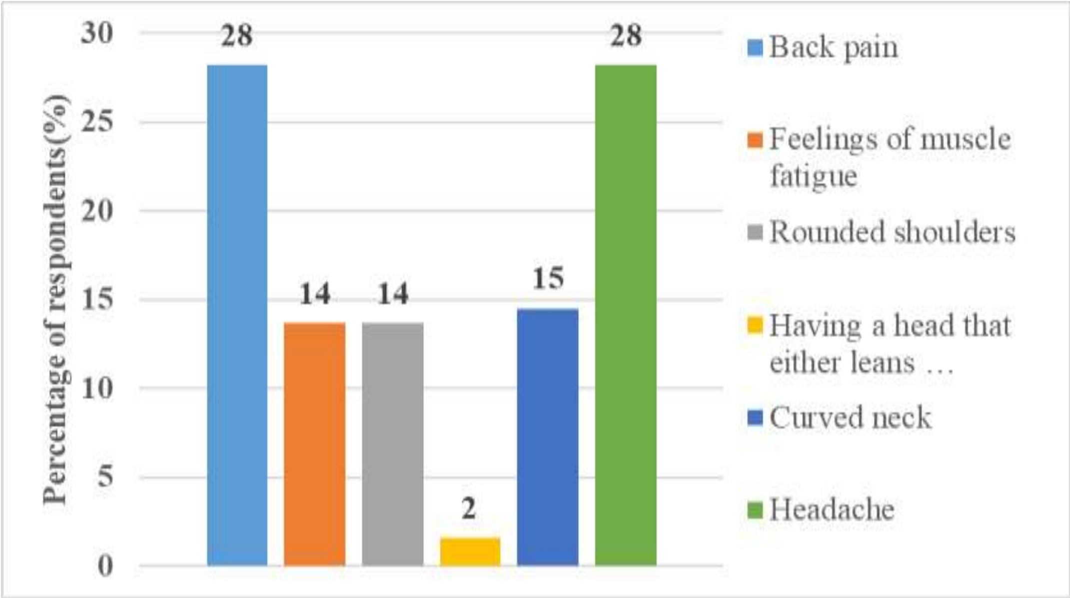

Figure 4.2: various impacts of poor body posture

This study also assesses the various impacts of poor body posture Figure 4.10. Indicate that, the most significance impact are rounded shoulder and back pain with 56% of respondent who confirm this statement. This research in line with difference researchers who report the same impacts [13], [14] and [23].

4.2 Need for using wearable device

The Wearable Spine Posture and Shoulders Corrector (WSPSC) is a medical device designed to address issues related to poor posture, particularly rounded shoulders. It achieves this by employing materials that restrict the movement of the trapezius muscle and scapula while incorporating electrodes for electrical nerve stimulation to aid in the reconstruction of vertebral ligaments [23].

Recognizing that poor posture is often influenced by sitting positions, this study aimed to develop a prototype of a wearable device for stabilizing the cervical spine and shoulders, assisting individuals in correcting poor body posture and rounded shoulders, ultimately restoring a normal spinal curve and preventing bad posture. Moreover, the research findings revealed unanimous support, with 100% of surveyed participants expressing the need for such a wearable device to assist individuals affected by the consequences of poor posture. Figure 4.11 illustrates respondents' willingness to utilize the wearable device, highlighting its significance in addressing poor posture issues [insert relevant citations for "Different studies depict the importance of a wearable device for poor posture correction"[7], [8] and [114].

4.3 Sustainable solution for correcting bad posture

4.3.1 Existing solution of Spinal Deformities

The normal spine is structurally balanced for maximum flexibility and weight support. It has three gentle curves when viewed from the side. Lordosis is an inward curve in the lumbar (lower) spine. Kyphosis is an outward curve in the thoracic (middle) spine. The cervical spine (neck spine) also has lordosis. These curves work together to keep the center of gravity of the body aligned over the hips and pelvis. The normal spine is straight when viewed from behind. An abnormal curvature of the spine can cause it to be out of alignment. Sagittal imbalance refers to abnormal curvature seen from the side. Kyphosis, flatback syndrome, and chin-on-chest syndrome are all examples of sagittal imbalance [36].

Scoliosis is defined as an abnormal curvature of the spine as seen from the back. Each of these conditions can develop for a variety of reasons, including congenital deformity (birth deformity), age-related degeneration, disease processes such as tumors or infections, other conditions, or idiopathic causes (causes that are not yet understood) [115].

- **Diagnosis of spinal deformities**

Various tests can assess spinal deformities. X-rays, or plain films, generate bone images using electromagnetic energy (X-rays), but they don't reveal soft tissue structures or some conditions. They assess bone anatomy, vertebral alignment, and detect issues like spondylolisthesis, kyphosis, scoliosis, and spine balance. Specific bony abnormalities like spurs, disc changes, fractures, or erosion are visible. Dynamic X-rays, showing spine motion, check for abnormal movement. Magnetic resonance imaging (MRI) uses magnets and radio waves for detailed spine and soft tissue images. Computed tomography (CT) scans combine X-rays and computers for highly detailed images of bones and soft tissues, surpassing traditional X-rays[116].

4.3.2 Design a prototype of wearable spine posture and shoulders corrector

Mechanical support from exoskeletons has the potential to substitute, aid, or help rehabilitate upper limb function in individuals with mild to moderate shoulder impairments, enabling them to carry out everyday tasks. The current study created a wearable spine posture and shoulder corrector prototype (figure 4.3). This measurement is indicated by the SOLID WORK [117].

Figure 4.3. Wearable spine posture and shoulders corrector with TENS Machine

4.2 Summary

In the results chapter, it is planned to design an artificial plastic wearable device that will assist in correcting bad sitting posture. If the sitting posture performance of the participants does not meet the "good" standard, the device will make an accurate judgment and to begin effectively change the sitting posture of the human body. Unfortunately, due to a lack of time and financial resources, there is no standardized material that can be used. The current study aims solely to design a prototype of a wearable device that can aid in the correction of side effects caused by poor posture. It is limited in design only, which means there will be no calibration, testing, or experimentation, monitoring, or networking on device performance. Moreover, the final product of prototype has to be presented in this chapter.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The primary goal of this research is to assist people in maintaining good sitting posture and lowering the risk of serious diseases by developing a prototype of a wearable spine posture and shoulder corrector to assist people with bad posture and rounded shoulders in regaining normal thoracic curve and preventing bad posture. This study specifically, (1) To determine the history of back pain according to socio-demographic characteristics of the participants, (2) To determine the frequency of workstation adjustments used to prevent back pain and discomfort and (3) To determine the perception of the participants regarding factors affecting spinal posture at work. The study initiated with the establishment of the research question, aiming to explore the requirements and procedures essential for developing a prototype to address neck and shoulder stabilization. About 100% of respondents indicated that a prototyping of a wearable device is need to help people with bad posture to regain normal thoracic curve.

Additionally, this study suggests using an artificial plastic wearable device to help people reduce the disease risk factor of poor sitting posture. It does however, have the benefits of portability, strength, and low cost. Moreover, Good posture throughout the day's various activities is an important way to maintain spinal health. In addition, corrective exercises used in the treatment of some back problems such as scoliosis. With this in mind, postural control can be a useful mechanism to support therapy or an everyday tool for a conscious user to correct and adjust their posture in different situations.

Finally, a crucial aspect of the research involved the integration of TENS electrode placement for optimal muscle contraction in the wearable spine corrector. This innovative approach aimed to enhance the effectiveness of the device in assisting users to maintain proper posture.

In summary, the journey of designing and prototyping the wearable spine posture and shoulders corrector has encompassed an in-depth exploration of both quantitative and qualitative facets of the problem. By addressing these specific objectives, this study has laid the groundwork for the development of a practical and effective solution to promote healthy posture and prevent back-related issues. The findings and methodologies presented herein offer valuable insights for future research and innovation in the field of wearable healthcare technology, with the potential to significantly, improve the quality of life for individuals prone to poor posture and associated discomfort.

5.2 Recommendations

As mentioned, this study is all about the design only and final recommend the future researchers to take into consideration the following: incorruption of calibration button in the system, which is designed for spine and shoulder corrector by entering calibration mode.

Second, one is predetermined number of sensor readings related to the current position. These readings averaged to determine the new threshold limits, which are now used to monitor the posture. The device's features enable it to be more multipurpose among a diverse range of users with varying body shapes and sizes.

Third recommendation is for optimal device performance by monitoring, after the limits are set, the values of the sensing elements are reading repeatedly at a predefined interval and compared against the limits. When the readings exceed the values for an extended period (i.e. poor posture is detected), haptic feedback is provided. This process will be repeated until the readings return to normal.

In addition, not only is the preceding study required, but also networking is also essential. After the sensor readings are obtained, they are transmitted to electronic devices such as smart phones, where Bluetooth that can be created and used as an interface between the device and the user.

Generally, Wearable posture monitors, in general, have the latent to avoid the above-mentioned consequences by providing real-time feedback that encourages the rectification of continuously poor posture. Furthermore, long-term use of these systems is hoped to instill proper postural habits, resulting in a reduction in the frequency of posture-related Skeletal system disease.

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APPENDICES

Appendix 1: The Questionnaire

DESIGN A PROTOTYPE OF WEARABLE SPINE POSTURE AND SHOULDERS CORRECTOR

Hello,

My name is HABYARIMANA Eric, masters of Biomedical Engineering, Center of excellence in Biomedical Engineering and e-health at University of Rwanda

You have been identified as key person to participate in research project with the title : "**DESIGN A PROTOTYPE OF WEARABLE SPINE POSTURE AND SHOULDERS CORRECTOR**" This research is being conducted as part of a core requirement of the Masters completion in Biomedical Engineering at the University of Rwanda. questionnaire is to fulfil the requirement of Msc project in Biomedical Engineering, form the university of Rwanda. It is 12 questions that will take 5 min of your time to answer. This questionnaire will allow to collect data that will help me to know an impact of electronics tools such as computers and mobile phones on spine posture for long period . The purpose of this research is to design a wearable prototype for protect a spine posture and prevent rounded shoulders
Microsoft form is used to allow an automatic return of the questionnaire to me once completed. This questionnaire will expire in 2 weeks' time. Thank you in advance for your help.

* Required

1. **Gender of responder** *

- ◯ Man
- ◯ Woman

2. **Age of responder** *

- ◯ Less than 30
- ◯ Between 31-50
- ◯ Above 50

3. **What is your occupation in everyday life?** *

- ◯ Manager
- ◯ Officer worker
- ◯ Students
- ◯ Skilled worker
- ◯ Unskilled worker

4. **How long have you been in this job ?** *

- ◯ Less than 5 Years
- ◯ Between 6 -15 years
- ◯ More 16 years

5. **Did you have a back injury ?** *

- ◯ Yes
- ◯ No

6. **Which one of the following physical factors that influence spinal posture ?** *

- [ ] High visual demands
- [ ] Heavy lifting
- [ ] Repetitive work
- [ ] Sitting position
- [ ] Awkward position

7. **Do you experience any pain after long study of working or studying ?** *

- ○ Yes
- ○ No

8. **If yes, which one of the following do you experience ?**

- ○ Back pain
- ○ Neck pain
- ○ All above

9. **How often do you adjust your sitting position ?** *

- ◯ 10-20 minutes
- ◯ 21-30 minutes
- ◯ 31-40 minutes
- ◯ Above 40 minutes

10. **What are the impacts of poor sitting posture ?** *

- ☐ Back pain
- ☐ Feelings of muscle fatigue
- ☐ Rounded shoulders
- ☐ Having a head that either leans forward or backward
- ☐ Curved neck
- ☐ Headache

11. **Do you think wearable devices which help people to correct poor posture is needed ?** *

- ◯ Yes
- ◯ No

12. **If yes how often should it help ?** *

1	2	3	4