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Modeling the Impact of Sitting Posture and Duration on the Health and Safety of Remote Learning

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Abstract

This study investigates the effect of sitting posture on the back health of students involved in remote work. Jack® human simulation software was employed to measure the impact of different seated postures on the lower back region, specifically the lumbar spine. The analysis focused on common positions adopted during extended work periods: neutral (Posture 1), flexion (Posture 2) and extension (Posture 3). Three tests were conducted in the simulated environment to predict the forces exerted on the musculoskeletal system, which are Lower back analysis (LBA), Comfort Analysis, and Ovako Working Posture Analysis System (OWAS). The results revealed that Posture 2 exhibited the highest compression force and is the least comfortable in terms of joint angles compared to the other postures while posture 3 is the least comfortable in terms of body parts. Furthermore, the musculoskeletal loading associated with working in postures 2 and 3 does not reach excessive levels, however it is required to provide ergonomic improvements. This paper also proposes strategies to enhance the working postures of university students.

Keywords
Sitting Posture, Lower Back Analysis, JACK Software, Remote Working

1. Introduction

The protracted hours spent in sedentary work environments during the contemporary workday have yielded multifaceted repercussions on individuals' health. Prolonged sitting throughout the workday has been associated with musculoskeletal discomfort, and chronic back and neck pain, stemming from heightened spinal pressure and postural imbalances (Baker et al., 2018). Concurrently, extended periods of immobility contribute to cardiovascular risks, including elevated blood pressure and compromised circulation. Metabolic implications, such as weight gain and insulin resistance, are compounded by the sedentary nature of many jobs (Bellettiere et al., 2017). In addition, prolonged sitting is associated with an increased risk of obesity and diabetes, two interrelated health concerns that have become more prevalent in modern sedentary lifestyles. Extended periods of sitting contribute to weight gain through a reduction in energy expenditure and metabolic rate. Inactivity affects the body's ability to regulate glucose and insulin levels, leading to insulin resistance—a key factor in the development of 'Type 2' diabetes. Additionally, sedentary behavior may promote the accumulation of visceral fat, which is linked to metabolic disturbances. Beyond the physical realm, mental well-being is also largely affected, with increased stress and a potential link to depression (Pears et al., 2022). Recognizing these health concerns underscores the imperative of integrating strategies to introduce movement, and breaks into the work routine, thereby mitigating the adverse consequences associated with prolonged sitting during working hours.

1.1 Objectives

This study aims to measure and analyze the effects of different sitting postures that are frequently seen among students who engage in long hours of sedentary activities such as reading, studying, etc. In this study, the effects of different sitting positions will be examined in a simulated environment to look into how the back is impacted using several analyses. The gathered data is then discussed on how overtime can lead to physical health complications. Finally, a few evidence-based recommendations will be suggested for university students to set up their remote learning environments in an ergonomically friendly manner.

2. Literature Review

Indeed, maintaining the correct sitting posture is pivotal in mitigating the adverse effects of prolonged sitting. A proper posture, characterized by a neutral spine, supported lower back, aligned head and shoulders, and 90-degree angles at the knees and feet, distributes body weight evenly, reducing the risk of chronic back pain, stiffness, and musculoskeletal issues (Corlett, 2006). Incorporating ergonomic furniture further supports good posture. However, even with ideal sitting habits, taking regular breaks to stand, stretch, and move is crucial to preventing the negative consequences associated with extended periods of sitting. By conscientiously adhering to these practices, individuals can significantly enhance their comfort and minimize the potential health risks associated with sedentary lifestyles.
However other sitting postures may result in various adverse effects. For instance, sitting upright without a backrest may lead to a slight lean frontwards. It can lead to adverse effects such as poor posture, increased strain on the lower back, muscle fatigue, and discomfort. The absence of proper lumbar support may contribute to spinal misalignment, potentially causing musculoskeletal issues over time. Additionally, sitting without back support increases the pressure on intervertebral discs, and the waist, hence may reduce overall comfort, focus, and relaxation (Yoo, 2012). Prolonged use of chairs without backrests can heighten the risk of falls and limit the ability to fully relax during breaks. To mitigate these issues, individuals should be mindful of their posture, take regular breaks to stand and stretch, and consider ergonomic seating options to promote musculoskeletal health.

Leaning the body back with the lower back hanging in the air, often referred to as a reclined or slouched posture, as can lead to various adverse effects on the spine and musculoskeletal system. This position places increased stress on the lower back, as the natural lumbar curve is compromised, potentially leading to discomfort and chronic pain over time. The lack of support for the lower back can contribute to poor spinal alignment, increasing the risk of musculoskeletal issues (Ran et al., 2021b). Additionally, this posture may strain the neck and shoulders as the body attempts to compensate for the imbalance, leading to tension and potential discomfort in those areas.

Sitting without a backrest is a significant cause of stress on the lumbosacral discs. Additionally, the sitting position can lead to an increased problem of musculoskeletal disorders and lumbar discomfort (K.-S. Jung et al., 2020). The lack of support at the lumbar spine places more pressure on this area of the spine than it is capable of bearing causing pain that can become a chronic musculoskeletal condition. Front sitting without back support affects the soft tissues and joints of the spine. These are anatomical components that are greatly stressed by such postures, leading to a loss of flexibility and balance besides illustrating a close relationship between muscles and bones. Additionally, front sitting without appropriate back support in the soft tissue and joints within the body's spinal column. Moreover, lack of back support for two hours is a trigger to fatigue and stiffness (Chatchawan et al., 2015). This high level of stress on these anatomic components does not imply a loss of flexibility and stability, it also emphasizes the relationship between the musculoskeletal systems.

The impact of sitting posture and duration on the health and safety of remote learning could be further understood by examining the influence of the body tilting to the left or right during sitting. This sitting position alters the body's center of gravity, potentially causing spinal deformation (Jennifer Huizen, 2023). The posture is often understood as a sitting position in which an individual sits slumped to one side, and the spine is forced to take a bent shape. The consequences of this posture include misuse and overuse of certain tendons, ligaments, and muscles (Jennifer Huizen, 2023). Loss of balance and back pain are the most common health outcomes of this sitting position. The spine is the central axis and pillar of the human torso, it has evolved in a biomechanical manner that allows it to not only maintain balance but also body posture (Li et al., 2022). Muscles help hold in position the different axes that constitute the spine, this posture disorients the muscles by causing unequal contractions, and in the process, the physiological curvature of the spine changes. Extended time of this sitting posture is linked to spinal abnormalities (Li et al., 2022). Children are even at a higher risk of experiencing spine deformation due to long sitting hours of the left sitting/right sitting posture (Li et al., 2022). Their skeletal systems experience active growth and development, which means that their spines are exposed to deformation, especially now that their anterior and posterior curvatures have yet to mature (Li et al., 2022). Altered structural development of the spine due to left sitting/right sitting posture is closely associated with Scheuermann's Kyphosis and impaired lung function.

It is usual practice to cross one's legs while sitting, either left over right or right over left. While crossing one's legs can be comfortable and provide immediate relaxation, sitting in this position for an extended period can cause a number of musculoskeletal problems. Research shows that sitting with legs crossed results in higher lumbar spine strain and asymmetry in spinal loading than sitting with feet on the floor (Ahn, 2019). When one's legs are crossed, the uneven distribution of weight can compress the nerves and discs on one side of the lower back, causing discomfort and severe back pains (Ahn, 2019). Leg crossing also results in an exterior rotation of one hip and an internal rotation of the other, causing uneven strain on the hip joints, waist, and surrounding muscles (K. Jung et al., 2020). Back discomfort may become worse due to this unbalanced hip posture, which can also cause the lower spine to curve and change pelvic alignment (Lee et al., 2016). Finally, the knee joint on the lower leg side is also strained since the top leg carries more weight. However, such conditions caused by sitting positions can be avoided by practicing the right sitting posture. Experts advise against spending a lot of time sitting with your legs crossed in order to reduce these problems. Periodically switch up your seating position, perform small stretches, and take regular standing intervals to balance the body's weight (Alsirhani et al., 2023). Another way to help distribute weight more equally is to elevate the foot of the upper leg with a footrest or small stool. Although it may feel more comfortable to cross one's legs, the greatest posture for long-term hip and spinal health is to have both feet on the floor.

2.1 Global Statistics

The impact of sitting posture and prolonged sitting position on one's health with regard to remote learning has been studied hugely. Multiple studies provide statistics that provide insight into the health challenges that people face when they sit for a prolonged period or sit poorly on screens. Musculoskeletal and cardiovascular issues are the most prevalent health challenges that are associated with poor sitting positions. Statistics show that work-related musculoskeletal disorders in the United States caused 33% of sick leave (Zhang et al., 2023). A key risk factor is a static and unpleasant sitting posture. Researchers say that a flexed neck is positively attributed to neck pain, and a forward-leaning posture contributes to a high rate of back pain disorder discomfort (Zhang et al., 2023). The rate of health-related issues related to prolonged sitting and poor sitting posture increased during and after the COVID-19 pandemic. There were records of multiple complications due to the introduction of remote working, in which individuals spent most of their time sitting on a desk for an extended period without breaks. In Italy, the number of remote workers increased by 69% and 81% worldwide. lower back pain issues ranged from 1.4% to 20%, while neck pain prevalence for the general population was recorded to be 3.6% (Moretti et al., 2020). However, these health issues can be prevented by adopting a good sitting posture and taking breaks after a while to reduce fatigue.

Remote learning involves long hours of screening, and less physical activity contributes to individuals developing health complications. The World Health Organisation set some recommendations that help limit sedimentary behavior, which is prevalent among children in the contemporary world. The WHO recommends that children should engage in

60 minutes of moderate to vigorous physical activity a day. Additionally, WHO recommends that parents should limit the amount of time spent by their children on sedentary activities, particularly screen time (Chaput et al., 2020). People are prone to develop mental health complications such as depression when their sedentary behavior is high. Sedentary practices, such as using a computer, can obstruct direct contact between persons, resulting in a decrease in social connection and an increase in the risk of depression (Huang et al., 2020). Statistics show that 95% of sedentary behaviors were associated with the risk of depression (Huang et al., 2020). The main goal is to ensure that people remain healthy, limit sedentary behavior, and adopt the recommended sitting posture.

The shift to remote learning has caused workers, students, and educators to spend more time in front of screens. As a result of this behavior, they fail to engage in the required set of physical activities. Also, they are less knowledgeable about the sitting posture, which will put them at risk of health complications. Front sitting without a backrest left and right sitting are poor sitting positions that result in musculoskeletal issues. The recommended sitting posture is sitting with legs crossed. This sitting posture offers temporary relaxation to the lower limbs and plantar muscles (K. Jung et al., 2020).

3. Methodology

Human simulations in a virtual environment mimicking real-world postures are used to test ergonomics in sitting positions. Through this approach, you can measure angles precisely and then analyze the data quantitatively using an analysis tool that is able to acquire them. The methodology proposed in this study is simulating the environment by utilizing Siemens Jack software (Tecnomatix Jack®). This simulation tool can be used to generate 3D environments, and model human bodies with fitting anthropometric and biomechanical characteristics, all while performing ergonomic and human factors analysis (*Jack Base Manual*, n.d.).

4. Data Collection

4.1 Simulated Postures

The simulated human in this study was investigated considering three sitting positions displayed in Figure 1. These postures were recreated in the simulation from widespread sitting positions that are common among students (as discussed previously). Posture 1 (left of the figure) is considered to be a *natural* position, while Posture 2 (center of the figure) and Posture 3 (right of the figure) are deemed to be very common positions when engaged in various activities for long hours. The postures were mainly based on the manipulation of the customizable joint angles and seating positions mainly centered around the joints displayed in Table 1.

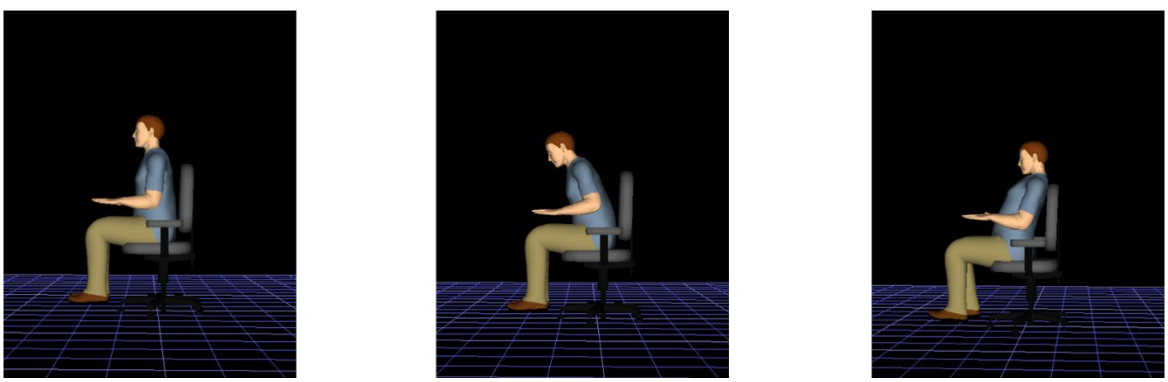

Figure 1. The three simulated postures.

Table 1. Posture torso, base of neck, and hip joint angles of the studied postures simulated in Jack®
.

Posture	Torso Flexion Angle	Base of Neck Flexion Angle	Hip Joint Angle
1	0°	0°	90°
2	20°	10°	90°
3	-30°	30°	88°

4.2 Anthropometric Measurements

Jack® allows you to size your human models for a specific worker population with multiple parameters such as gender, size, weight, etc. For this study, the selected anthropometric measurements displayed in Figure 2 were selected based on the mean height and weight data of an average man in the UAE (WorldData.info, n.d.).

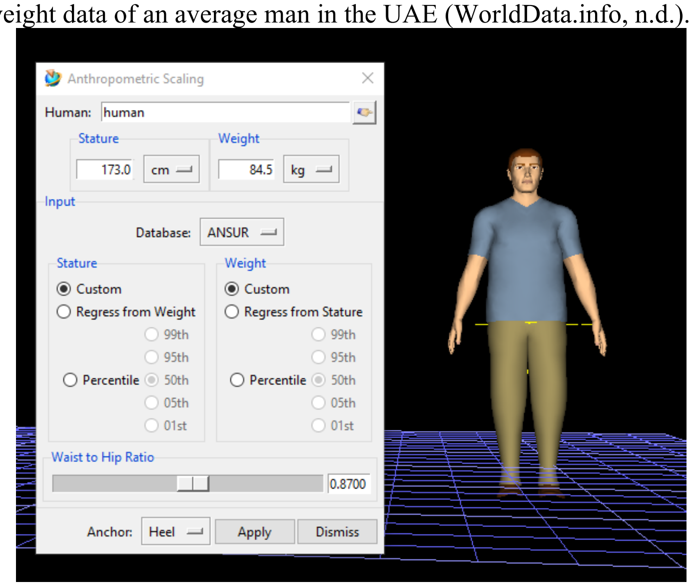

Figure 2. Designated anthropometric measurements of the human.

4.3 Simulation Analysis

Tecnomatix Jack® provides a Task Analysis Toolkit (TAT) that contain various analyses and ergonomic compliance checks directly within the simulated environment. Three analyses were performed and reported in this paper: Lower back analysis (LBA), Comfort Analysis, and Ovako Working Posture Analysis System (OWAS).

5. Results and Discussion

5.1 OWAS Analysis

Ovako Work Posture Analysis System (OWAS) is a straightforward approach used to assess the safety level associated with work posture and to determine the corresponding risk level that necessitates corrective action (Wahyudi et al., 2015). Figure 3 shows the OWAS evaluation for the three remote working postures. Posture 1 follows Category 1, which indicates that there are no hazardous effects on the musculoskeletal system for this posture, and no action is required (Özkaya et al., 2018). On the other hand, both Posture 2 and Posture 3 are included in Category 2, i.e., these working postures have some hazardous effects on the musculoskeletal system, therefore it is necessary to provide ergonomic improvements as a future strategy (Özkaya et al., 2018).

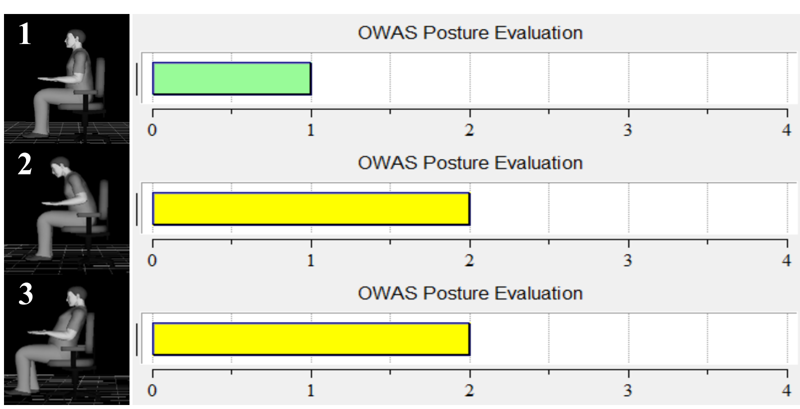

Figure 3. OWAS analysis for Posture 1, Posture 2, and Posture 3.

Table 2. OWAS codes

Posture	OWAS Code
1	1111
2	2111
3	2111

It should be noted that OWAS analysis only considers the downward force component. Table 2 reports the 4-digits OWAS code for each posture. This coding system was first developed by (Karhu et al., 1977). Here, code 1111 for Posture 1 suggests that the human is sitting in a straight back position (zero flexion angle), with two arms below shoulder level, and a load of less than or equal to 10 kg. Hence, the observed work posture appears to be within the expected normal range and in alignment with natural body mechanics. Thus, the musculoskeletal system experiences a tolerable level of postural strain and no requirement for implementing corrective steps. As for Posture 2 and Posture 3, they follow an OWAS code of 2111. The "2" indicates a bent in the back position, specifically forward bent in Posture 2, and backward bent in Posture 3. Such working positions may cause damaging effects on the spine alignment. The musculoskeletal loading associated with these two positions does not reach excessive levels; however, it is advisable to implement remedial interventions.

5.2 LBA Analysis

The lower back analysis (LBA) in JACK simulation is a tool used to evaluate forces acting on the L4/L5 lumbar spine during human activity. The lumbar spine, with five vertebrae, denoted as L1-L5; is positioned below the cervical and thoracic parts of the spine. The mobility of the L4-L5 spinal segment serves several roles, such as providing support to the upper body and facilitating multi-directional trunk motion. The L4/L5 force analysis for each seating posture is displayed in Figure 4 (a-c). Posture 2 exhibited the highest compression force of 1081 N. The recorded value falls below the NIOSH Back Compression Action Limit (3400 N), indicating a minimal level of risk for low back injury among most healthy students. Whereas Posture 3 applies less compression force on the spinal discs with a value of 762 N. Moreover, Posture 1 revealed the lowest L4/L5 force of 637 N, which again falls below the NIOSH limit.

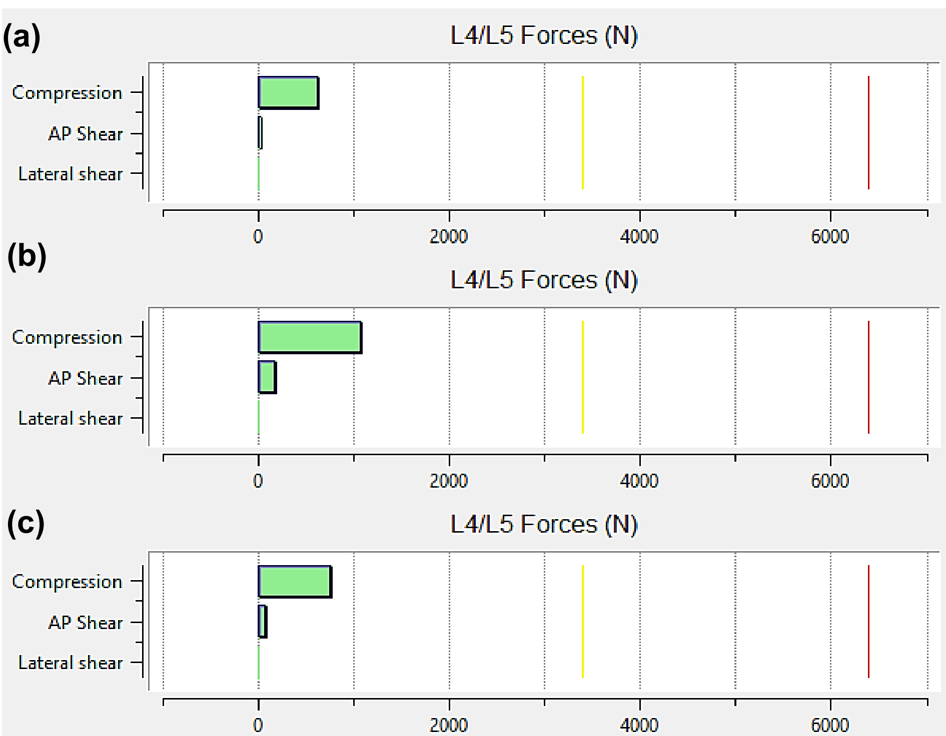

Figure 4. L4/L5 forces analysis for: (a) Posture 1, (b) Posture 2, (c) Posture 3.

Figure 4 also presents the anterior/posterior (A/P) joint shear force on the L4/L5 level. Posture 1 showcased a negligible AP shear force, which increased for Posture 3, and reached an even higher value for working in Posture 2. The reason for the larger forces acting on Posture 2 can be explained by the absence of back support, which in other cases helped reduce the load on the lumbar spine. No lateral shear forces were detected in any of the postures.

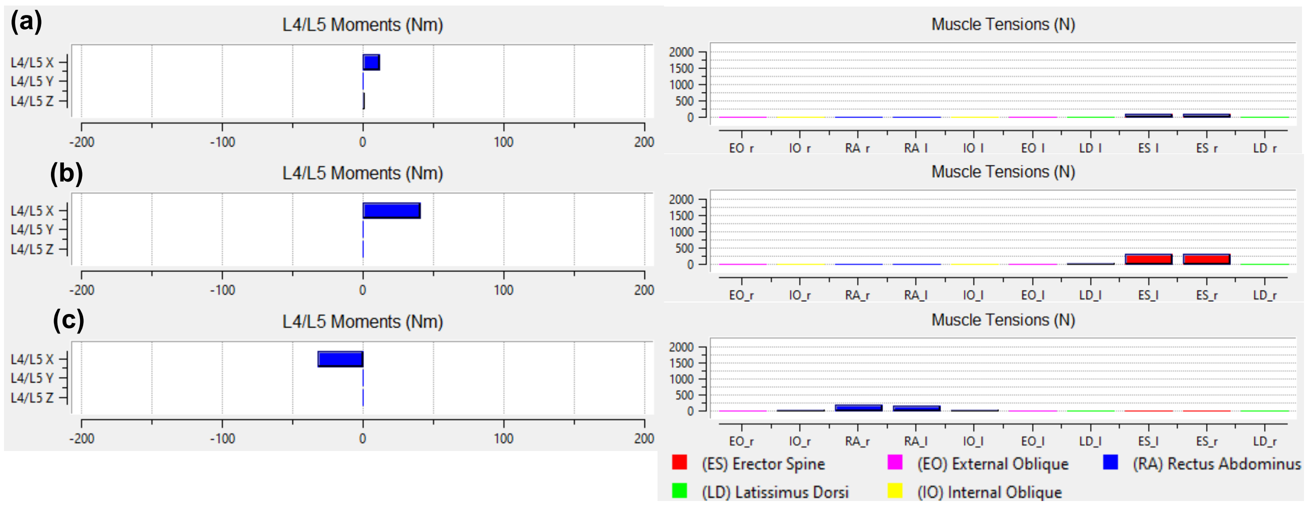

Figure 5. L4/L5 moments and muscles tensions analysis for analysis for: (a) Posture 1, (b) Posture 2, (c) Posture 3.

The moments, or torques, exerted on the L4/L5 vertebral segment by the three sitting postures are shown in Figure 5 (a-c). All postures generated rotational forces around the x-axes of the vertebrae. Posture 1 produced slight positive moments of around 20 Nm which indicates a small tendency to bend forward. Likewise, Posture 2 exerted larger positive moment forces (clockwise when viewed from above) of about 43 Nm which suggests a proclivity for spinal flexion. Conversely, Posture 3 generated moments around 40 Nm in the negative direction (counterclockwise when viewed from above). This position indicates the tendency of the spine to bend backward (extension) at the L4/L5 level. The LBA method also considers the muscles tension force applied on the lumbar. In this analysis, the forces created by contracting five different muscles in the body are measured and reported in Figure 5. The only muscle tensions detected in Posture 1 and Posture 2 were the ones exerted on the erector spine (ES) muscle. The ES muscles exhibit contraction as a compensatory mechanism to account for the delay in the progressive enhancement of lumbar spine stiffness and provide significant stability and support to the spinal cord (Smith et al., 2008). Posture 2 unveiled an ES muscle tension of higher than 250 N, which could affect extending the spine and risk keeping an upright sitting posture. A human working in Posture 3 will exert a Rectus Abdnominus (RA) muscle tension of about 250 N. This muscle plays a key role in various movements and functions, including trunk flexion, stabilization of the spine, and support of the internal organs (Smith et al., 2008). The presence of excessive tension in the rectus abdominis muscle might potentially lead to an elevation in intra-abdominal pressure. Overall, the LBA results confirmed that L4/L5 forces applied on Posture 2 are the greatest compared to the two other sitting postures, hence it is the posture with the highest lower back pain risk.

5.3 Comfort assessment

A third and final tool was utilized in order to assess all three postures via JACK software, which is the comfort assessment tool. The porter (1998) data source measures the joint angles based on the human seated posture as shown in Figures 6(a-c) for postures 1-3, respectively. The orange dash for each bar graph indicates the joint comfort range which is based on previous data with the green color indicating comfort while yellow indicates discomfort. This study is primarily focused on the back. However, the seated posture which is hugely governed by the back posture also has consequences on the rest of the body parts as the complex musculoskeletal system is interconnected. As shown in Figure 6, Posture 1 shows the most comfortable seating with Posture 3 being the second most comfortable seated position and Posture 2 being last. Posture 1 is the closest to a neutral position and thus, it is expected to be the best. However, it is still not the most ideal but in comparison to Postures 2 and 3, the measured comfort is either equal or closer to the comfort zone. Posture 2 is the least comfortable however it is one of the most common postures observed with a hunched over position among university students.

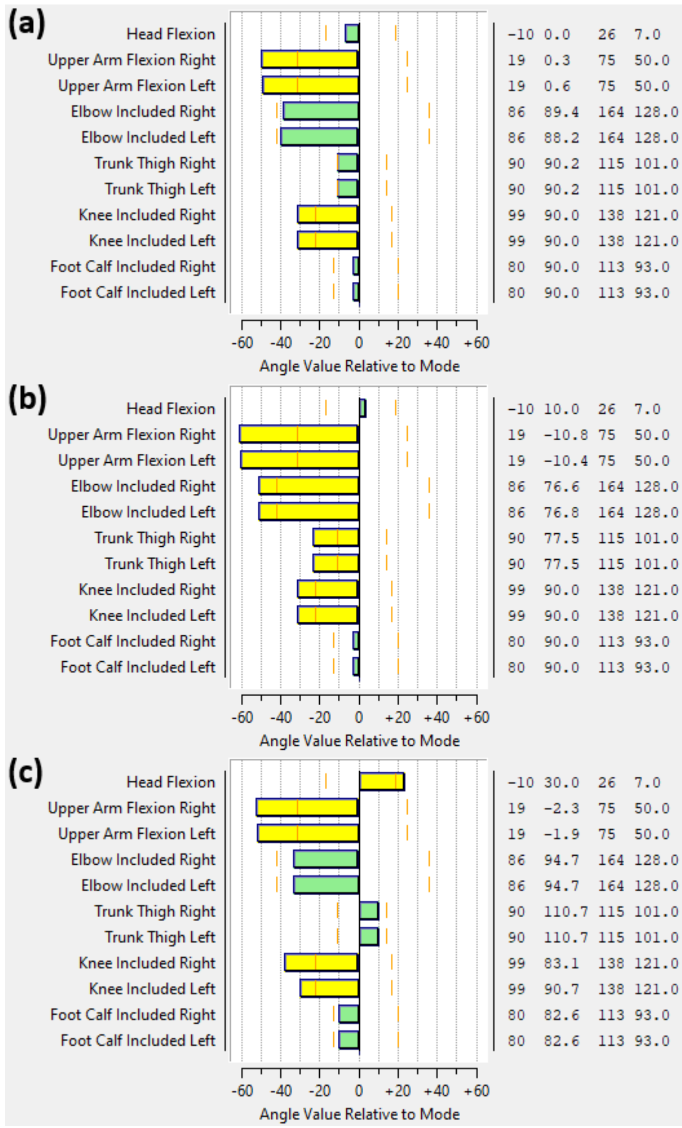

Figure 6. The comfort assessment ratings based on the Porter (1998) data source for: (a) Posture 1, (b) Posture 2, (c) Posture 3.

An additional comfort assessment was exploited however this time with a focus on body parts rather than joint angles using the krist (1994) data source as shown in Figures 7(a-c) for postures 1-3 respectively. The rating system in this case is based on a scale that goes from 0 to 80, best to worst comfort. Consistent with the previous assessments, posture 1 is the most comfortable with the back having the lowest score on the scale nonetheless unlike the joint angle based analysis, posture 3 is more comfortable in comparison to posture 2 on this scale. Overall, postures 2 and 3 need more improvements in comparison to posture 1 where fatigue is also rated higher.

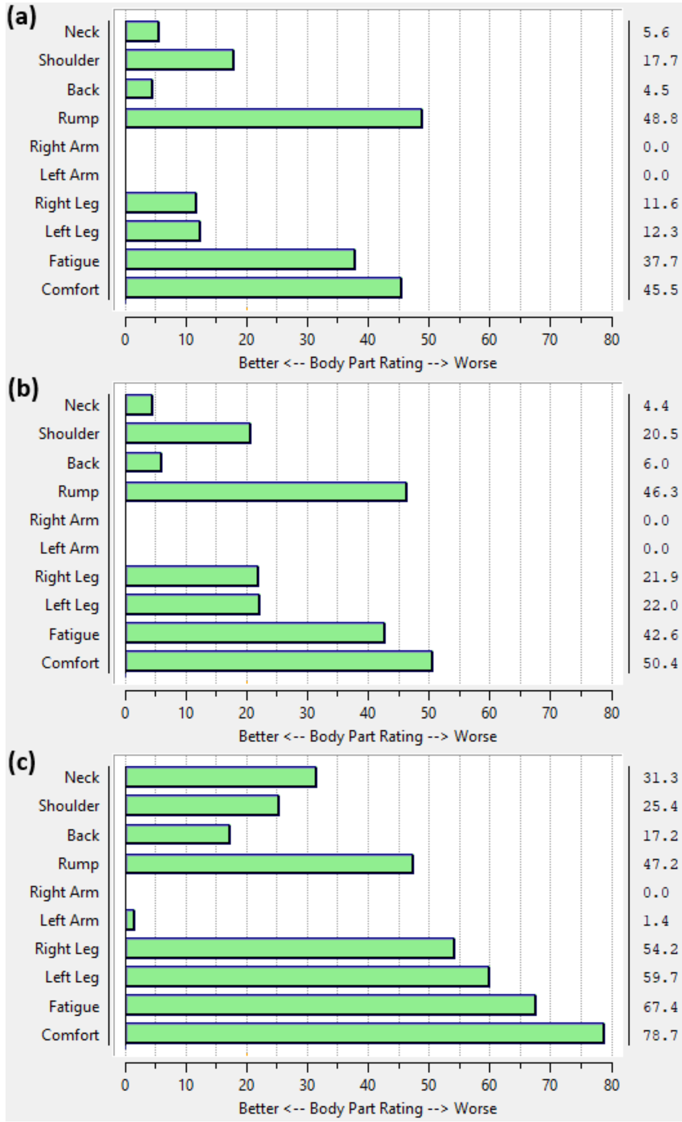

Figure 7. The comfort assessment ratings based on the Krist (1994) data source for: (a) Posture 1, (b) Posture 2, (c) Posture 3

5.4 Proposed Improvements

The implementation of online learning, especially in virtual universities is more popular than ever, as a consequence of the COVID-19 pandemic which made distance learning more feasible and acceptable. However, distant learning can bear some consequences on the health of students due to the excessively long hours spent on their electronic devices. Thus, the necessary resources must be allocated by universities by providing ergonomic chairs that support the natural posture to avoid the stresses imposed by unneutral postures such as the ones investigated in this study. The ergonomic chairs would offer a variety of features such as height control, headrests, rump support, and adjustable handrests. (Heller et al., 2023) investigated the sedentary time of German university students before and after the pandemic which alarmingly rose. Moreover, the authors were able to deduce that students who were highly physically active showed a lower increase in sedentary time than those who were inactive pre-pandemic. The latter puts emphasis on the importance of providing an ergonomic environment and the need for interval study breaks. Hence, an ergonomic chair is only one solution that should be complemented with a break program. Universities often use online portals and the integration of a reminder and instruction system in taking breaks could be easily implemented as a cost-efficient solution, this way, students can be fully involved in their studies while being managed with an automated system. (Heller et al., 2023) highlighted the existence of different models that encourage physical activity for university students, such as the smart moving project (Helten & Shaker Verlag, 2022) implemented in a German university. The model incorporated tools such as online active breaks (Heller et al., 2023). In fact, in (Heller et al., 2023) approach, they created an intervention that incorporates short videos inserted in online lectures. Such systems can be implemented nationally (UAE) and internationally with customizable packages that better suit the schedules of the universities.

6. Conclusion

In summary, this study successfully achieved its objectives of measuring and analysing the effects of various sitting postures usually observed among students working from home. The investigation utilized Jack® human simulation software to assess the impact of different seated positions on the lower back muscles. The findings notably highlighted Posture 2 (flexion) as having the largest L4/L5 forces and highest discomfort levels, despite being the most observed posture by students. Moreover, sitting in a posture with forward or backward bend may cause harmful effects on the spine alignment. Lastly, evidence-based recommendations to improve the ergonomic aspects of remote learning environments have been formulated based on the study's outcomes.

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