An Atlas Injury Prevention Solutions White Paper

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Office Ergonomics Trends Part II Update: Relationship between Products and Discomfort

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Introduction

How well do we understand the link between the ergonomic products individuals use and the onset of discomfort within an office environment? This is an update to our December 2008 white paper, using more recent data and increasing our study size from 2,441 to 26,469 employees.

Overview & Data Collection

Data was collected from multiple office environments during a 9-year period between 2009 and 2017.

Definitions

A review of the terms used during the analysis and development of graphs.

Participants

There were 26,469 employees evaluated for the study. The characteristics of the population involved in this project are presented.

Products vs. Discomfort

The relationship between the use of specific ergonomic products and reported levels of discomfort are reviewed and updated based on the new data set. Recommendations on how the findings should impact an ergonomic assessment are provided.

Conclusions

A review of the relationships learned and primary considerations.

INTRODUCTION

In this update of our original three-part office ergonomics white paper series, Atlas Injury Prevention Solutions (Atlas) will revisit the relationship between employee use of ergonomic products and reported of discomfort. In 2008, Atlas initially set out to define these relationships in a two-part process. First, a survey was distributed to approximately 80 safety, health, and ergonomics professionals to determine their opinions on some office ergonomics risk scenarios that are dealt with on a day-to-day basis. This was used to establish the expected relationship between products and discomfort. This portion of this survey looked at three ergonomic products: office chair, keyboard tray, and computer type. Table 1 describes the results of the survey.

Table 1: Responses to Office Ergonomics Survey of Occupational Health Professionals

	Survey Questions	Yes
1.	Do adjustable features on a chair relate to lower levels of discomfort?	62%
2.	Does a keyboard tray result in lower discomfort in the hands/wrists?	56%
3.	Are laptop users at increased risk of developing work-related discomfort?	90%

Secondly, an analysis was completed using data from a population of 2,441 employees who had participated in the Atlas office ergonomics assessment process. The results were then compared to the responses from the survey as seen in Table 2.

Table 2: Comparison of Survey Responses and Analysis Findings

	Survey Questions	Response	Findings
1.	Do adjustable features on a chair relate to lower levels of discomfort?	Yes	Yes
2.	Does a keyboard tray result in lower discomfort in the hands/wrists?	Yes	Yes
3.	Are laptop users at increased risk of developing work-related discomfort?	Yes	No

Table 2 demonstrates that the original paper found a discrepancy between the opinions/expectations of industry professionals and the objective data analyzed on the impact of laptop use. This paper will revisit the original findings through a more recent and larger data set, as well as addressing other products commonly used in offices.

OVERVIEW AND DATA COLLECTION

In this update, Atlas will revisit the considerations that must be involved in the assessment of an office work station. The focus of our last paper was on the characteristics of the worker (demographics): *Office Ergonomics Trends Part I Update: Relationship between Employee Demographics and Discomfort*. This paper will focus on the workstation set up, including the equipment and accessories that are available, and its effect on employee's discomfort. As we found in the original paper, many times our expectations can be flawed and mislead us from the important aspects of the evaluation. Therefore, this paper will examine the relationship between office products and discomfort, the effect on productivity, compare our findings to current research, and discuss how those findings should impact the approach taken during an office ergonomic assessment.

For this update, data collection was completed using Atlas' web-based office ergonomics assessment software AtlasOffice™. Before an onsite assessment is completed, AtlasOffice™ generates an online survey for the employee to complete. This survey is used to supplement an onsite assessment by gathering data related to employee risk as one of the first steps in the process. Each question within the survey was designed to assess different elements of office ergonomic risk and has been chosen based on current research and standards. Although this survey addresses both workplace conditions and employee demographics, this paper will only focus on how products impact ergonomic risk in the office environment.

The survey begins by asking the employee to provide basic information to assist in defining their demographics as discussed in our previous paper. The next part of the survey consists of discomfort-related questions. The employee is asked if he/she is experiencing discomfort (Figure 1) and then is led to a screen to identify the location of the discomfort (Figure 2).

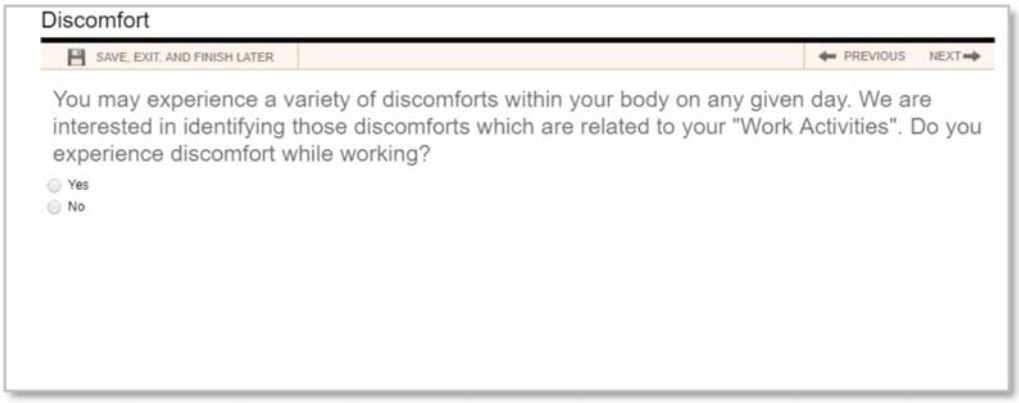

Figure 1: Prevalence of Discomfort

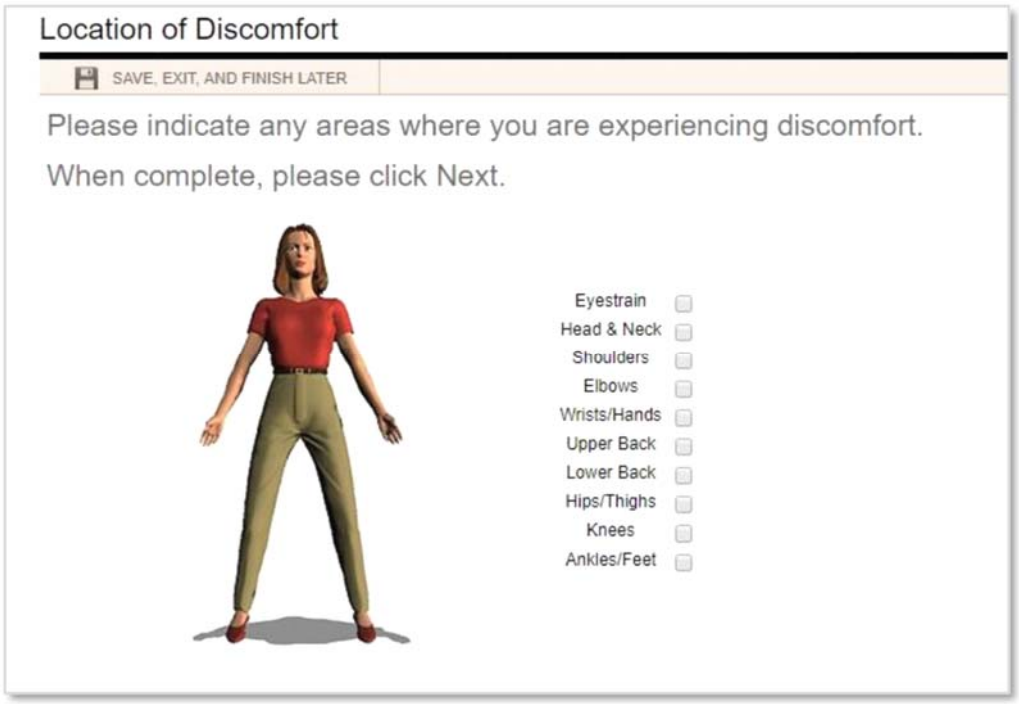

Figure 2: Area of Discomfort

Discomfort is then assessed in each area that the employee checked by using a health index. This uses a 5-point scale for frequency and severity of symptoms (Figure 3). The multiplicative value of these discomfort variables (F x S) is rated as low, moderate, high, and extreme.

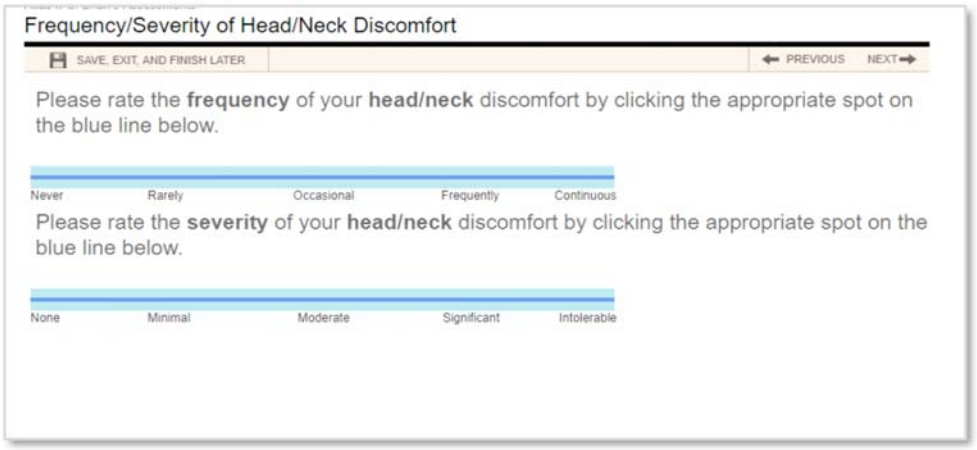

Figure 3: Frequency and Severity of Discomfort

The employee is then asked to rate their productivity loss. This uses a 5-point scale between 0 (None) and 4 (Continuous) to obtain a perceived loss of productivity due to their discomfort (Figure 4).

Figure 4: Effect on Productivity

Following the questions on discomfort and productivity, questions within the survey then focus on work tasks and equipment/furniture availability and setup. Figures 5 and 6 represent questions based on the products that are available to the employee.

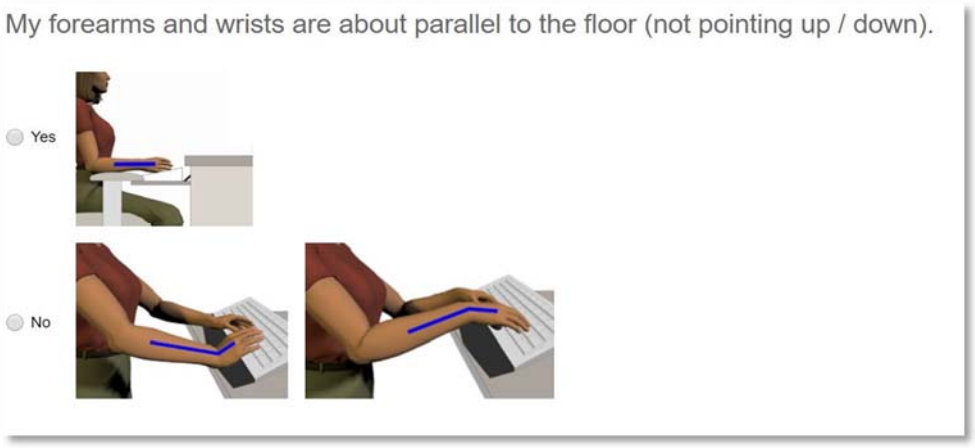

Figure 5: Position of Wrists on Keyboard

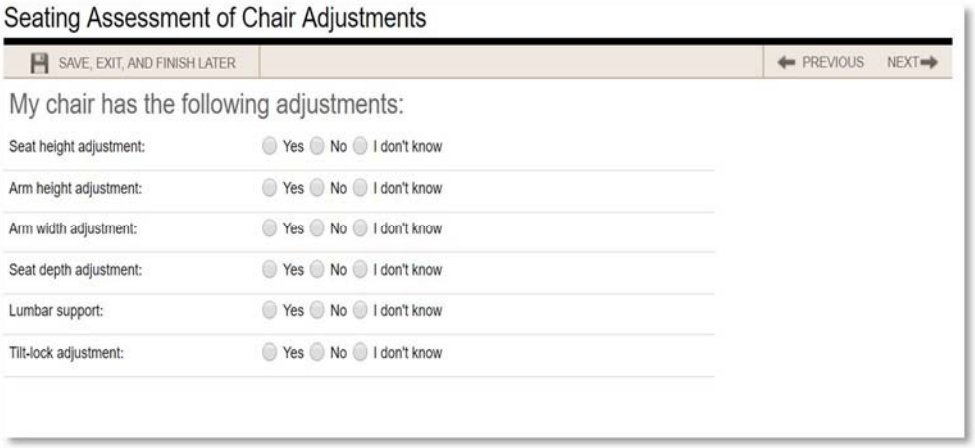

Figure 6: Chair Adjustment Availability

Ergonomic risk is assessed by comparing questions related to personal and task variables (e.g. height, BMI, hours of work) to an audit of the products and features that are present in the office. Using a logic table, any gaps in product availability and workstation design are identified.

Once the data has been submitted by the employee, it is available to an analyst in a checklist format to review and help with preparation for the onsite evaluation. Additionally, raw data can be downloaded into a spreadsheet for analysis and review.

DEFINITIONS

In order to compare product availability to discomfort, it was necessary to process the discomfort data and present it in formats that aided in viewing the potential relationships. Two key measures of discomfort were used to illustrate the interaction between demographics and discomfort:

Average Total Discomfort: In order to compare differences between groups, an average of the total discomfort scores across all employees in the group must be calculated.

Significant Difference: When comparing differences between groups, a T-test is used to compare the averages of the groups (mean). A probability value (*p*-value) is found to determine if the differences between the means are significant or are more likely due to chance. A significant difference would have a *p*-value <.05 or a less than 5% chance that the differences are due to chance alone. Therefore, when a significant increase or decrease is described below, the data demonstrates a *p*-value <.05.

In addition to these measures of discomfort, the data within this paper has been formatted to provide the most effective means of conveying a message. Additional descriptions of the methods used to create the graphs and format the data will be described as necessary.

PARTICIPANTS

This study included a population of 26,469 employees who completed an AtlasOffice™ online survey. These employees were from a subset of clients served by Atlas over the 9-year period (2009-2017). These companies come from a number of economic sectors, including aerospace, automotive, chemicals, consumer goods, healthcare, insurance, oil and gas, pharmaceutical, technology, and utilities. All employees were employed in an office position in either a traditional office setting or a home office setting. The figures below give a breakdown of the participants' demographic data.

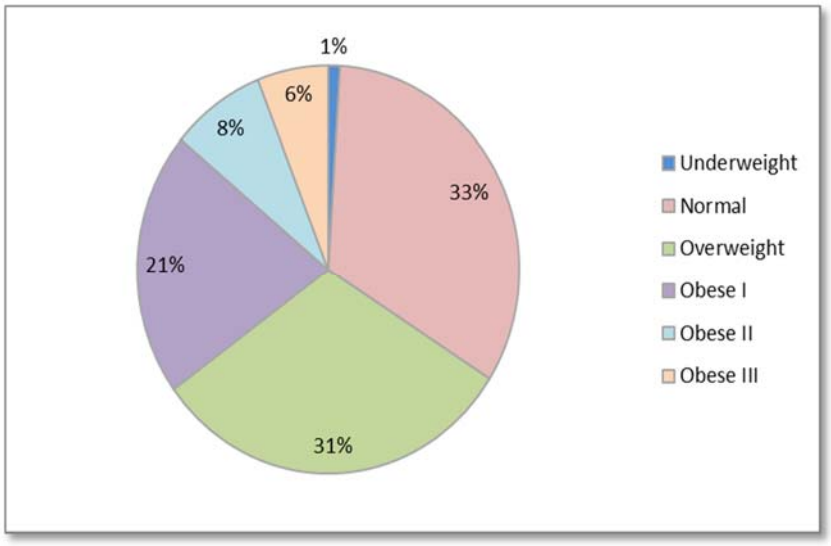

Figure 7: BMI Distribution

Figure 7 presents the breakdown of the study population based on body mass index (BMI). This data demonstrates a similar incidence of an obese and overweight population in comparison with the information collected by the Center for Disease Control (CDC) on the population by BMI classifications[1]. The CDC found an incidence of obesity in the US of 37.9% as compared to the study's finding of 35%. Also, the CDC found 70.7% of people either overweight or obese in comparison to the study's finding of 66%.

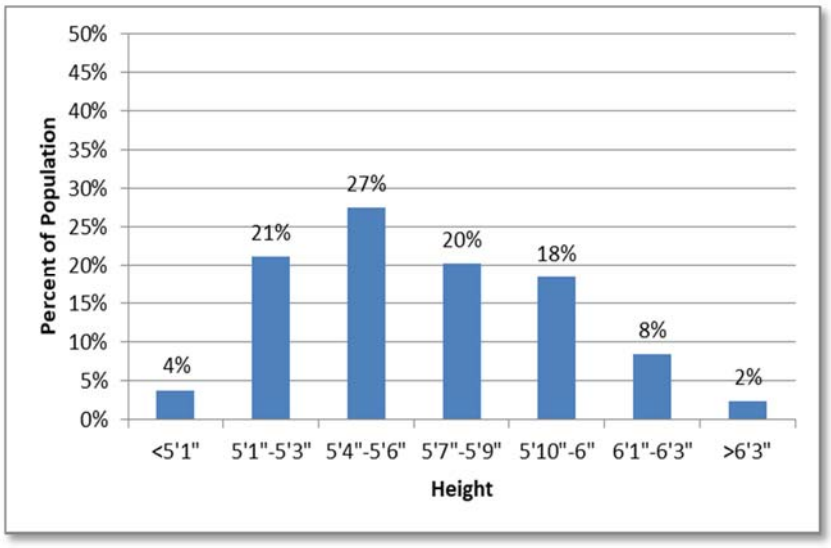

Figure 8: Height Distribution

Figure 8 presents the breakdown of the study population based on height. The figure shows a slight skew in the data towards shorter height ranges, but it is not far from a normal distribution.

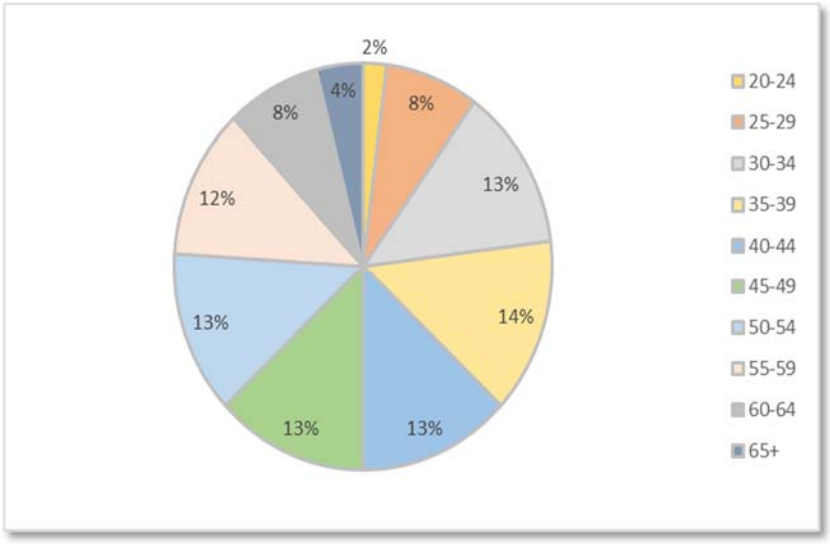

Figure 9: Age Distribution

Figure 9 presents the breakdown of the study population based on age.

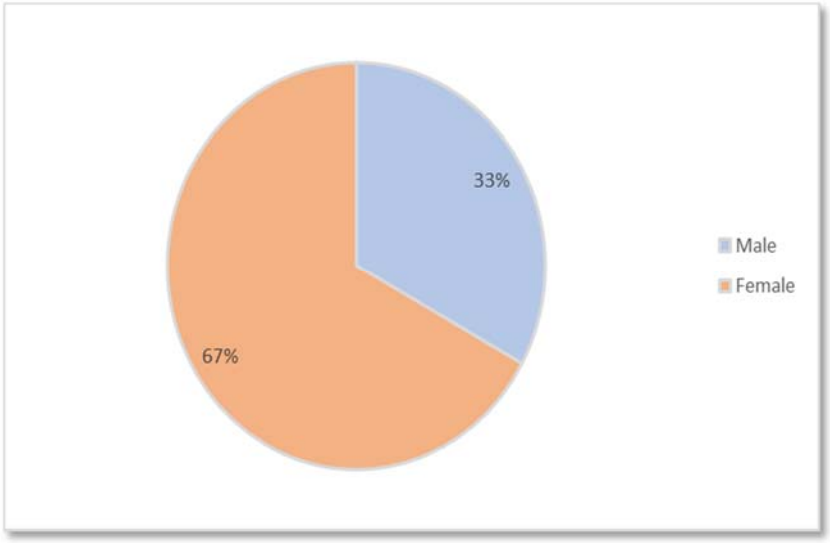

Figure 10: Gender Distribution

Figure 10 presents the breakdown of the study population based on gender. Women represent two-thirds of the total number of participants.

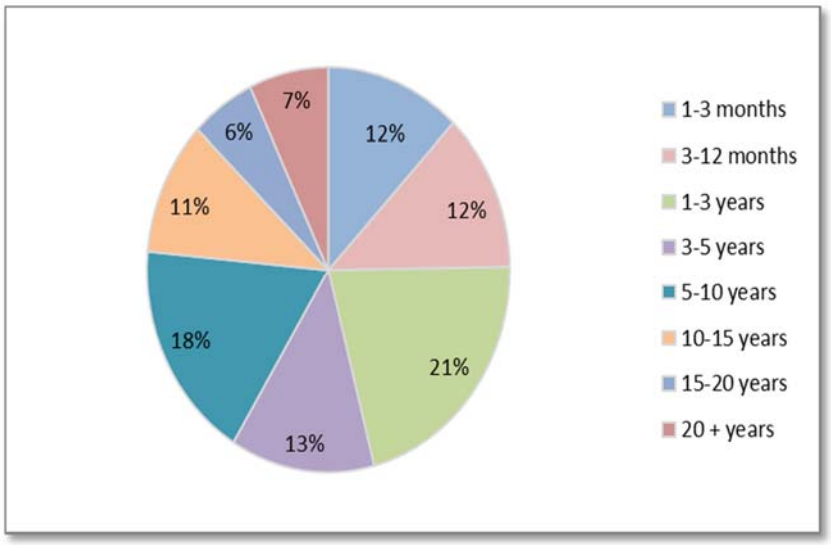

Figure 11: Job Tenure Distribution

Figure 11 presents the breakdown of the time participants have worked in their current position (job tenure).

PRODUCTS VS. DISCOMFORT

This update was tasked to review the findings of the original paper from 2008 and further investigate this topic with a larger and more recent data set. The products that are being studied are chair adjustability, type of computer, keyboard/mouse position, monitor position, and work surface adjustability.

Chair Adjustability

Similar to the 2008 report, there is a relationship between individual chair adjustments and reports of discomfort in specific areas. As expected, it is not merely the presence of the adjustments but the proper use as well. The availability of the following features was reviewed: seat height and depth, lumbar support, tilt lock, arm rest height and width. Also reviewed was the proper use of these features.

Seat Height is one of the most common adjustments found on the office chairs in our study. Ninety percent of employees report having a chair that has this feature. However, of those with this adjustment, only 60% report having proper position of their thighs and legs and 75% report having their feet flat on the floor. Proper chair height allows the employee to have a stable base by having his/her feet flat on the floor and thighs properly aligned with the floor. This adjustment affects the proper alignment of the spine. Figure 12 demonstrates there is minimal difference in discomfort throughout the levels of the spine between those who have and those who do not have a seat height adjustment on their chair.

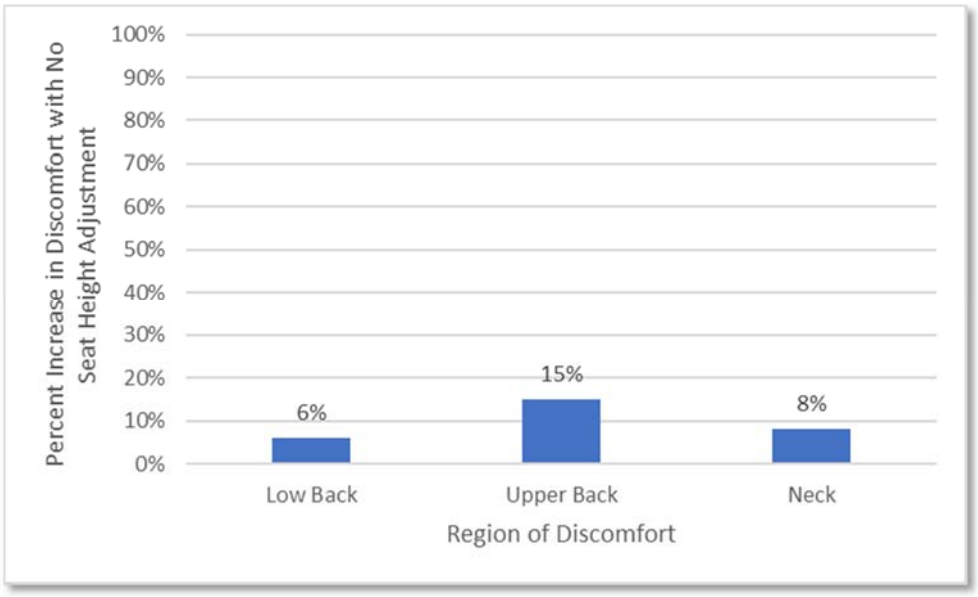

Figure 12: Percent Increase in Discomfort with No Seat Height Adjustment vs. Region of Discomfort

However, there is a greater increase in discomfort for those who do not have the setting adjusted correctly. Figure 13 demonstrates that employees who do not have their seat adjusted to allow their feet to be flat on the ground and thighs parallel to the floor have a significantly higher level of discomfort than those who report proper set up. This demonstrates the need for education for employees on proper chair height set up.

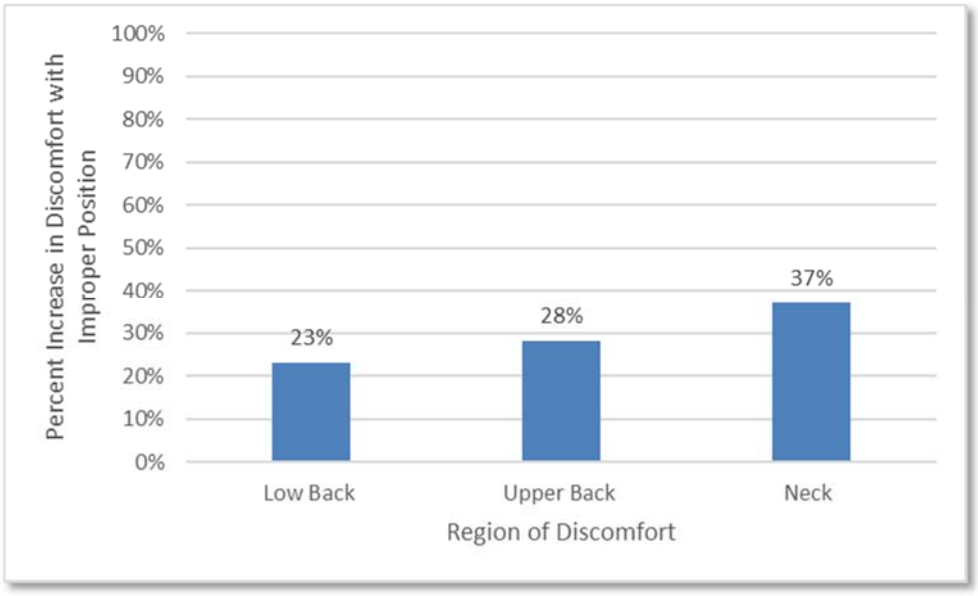

Figure 13: Percent Increase in Discomfort with Improper Positioning vs. Region of Discomfort

Seat Depth adjustability is not as common as seat height adjustability. In the data set we compiled, only 41% of individuals had this feature available to them. A chair with seat depth adjustability is expected to improve the fit of the chair for shorter and taller employees to match the anthropometry of their lower limbs. Specifically, it allows employees to have their feet flat on the floor as well as proper clearance for their legs on the front of the chair effecting primarily the spine and lower body. Figure 14 demonstrates the increase in discomfort in the low back and lower extremities. The analysis finds the only significant difference we see is in the hips/thighs related to this adjustment feature.

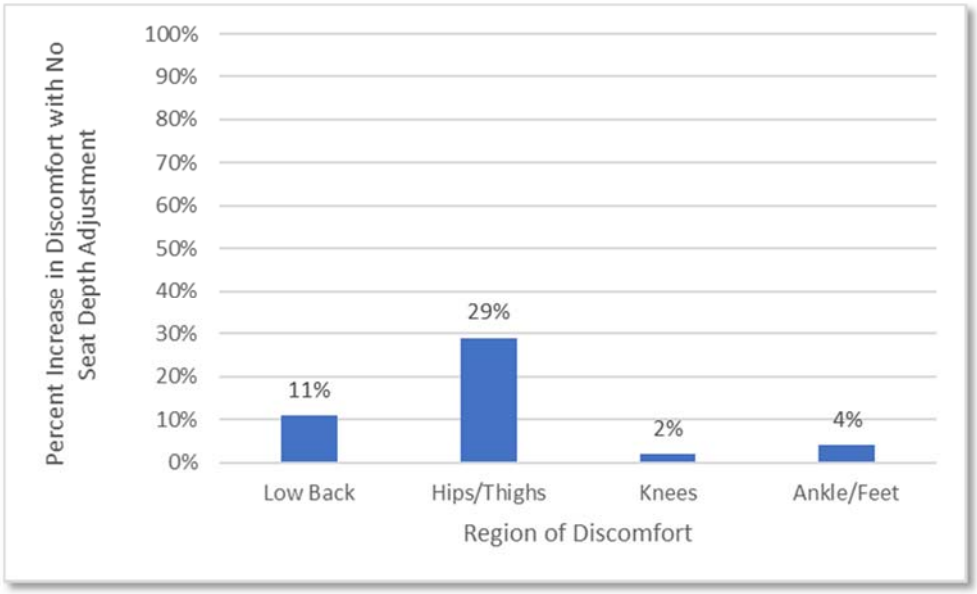

Figure 14: Percent Increase in Discomfort with No Seat Depth Adjustment vs. Region of Discomfort

Figures 15 and 16 demonstrates there is an even greater and significant increase in both these areas as well as in the feet/ankles when the chair is not set up properly to allow the feet to be flat on the ground and proper clearance behind the knees—giving further support to the need for proper education on chair features.

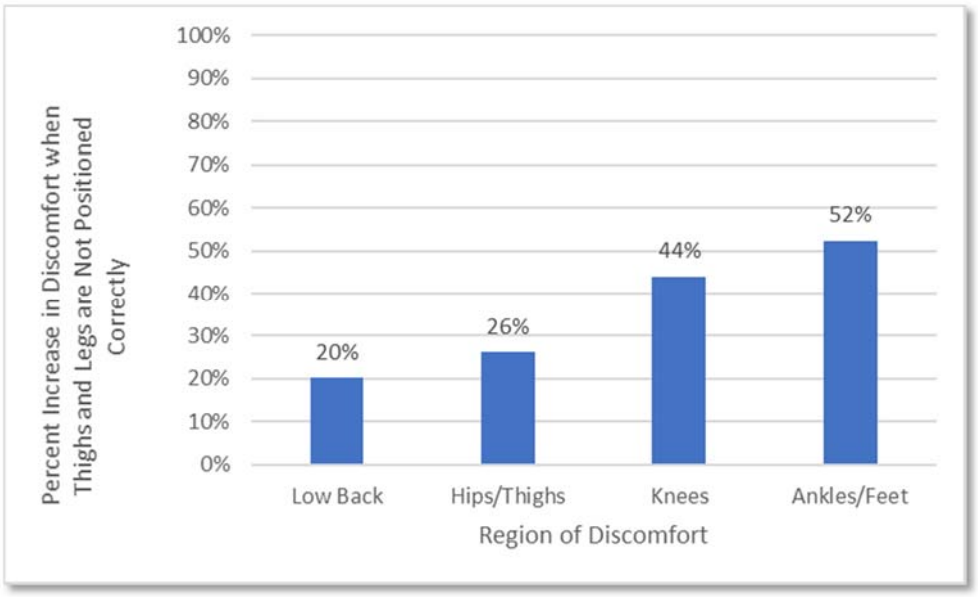

Figure 15: Percent Increase in Discomfort when Thighs and Legs are Not Positioned Correctly vs. Region of Discomfort

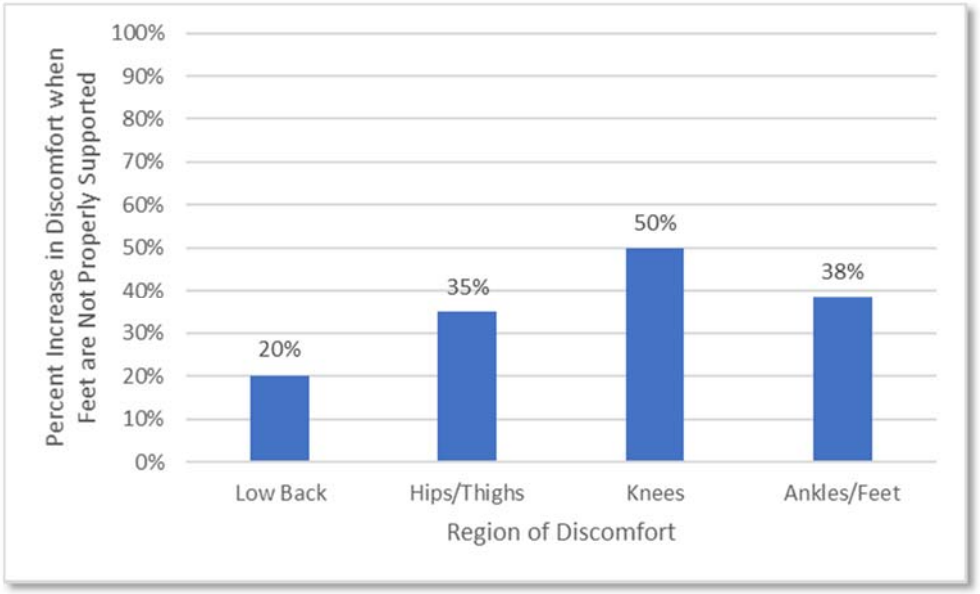

Figure 16: Percent Increase in Discomfort When Feet are Not Properly Supported vs. Region of Discomfort

Lumbar Support is an important feature that helps to maintain the lordotic curve of the lumbar spine, and encourages an upright posture that is supported by the entire length of the backrest. This will allow the neck and upper back to be positioned and supported as well as the low back. This feature was available to 46% of the employees in this data set. Figure 17 demonstrates the average increase in level of discomfort in each region of the back with the absence of lumbar support on the chair.

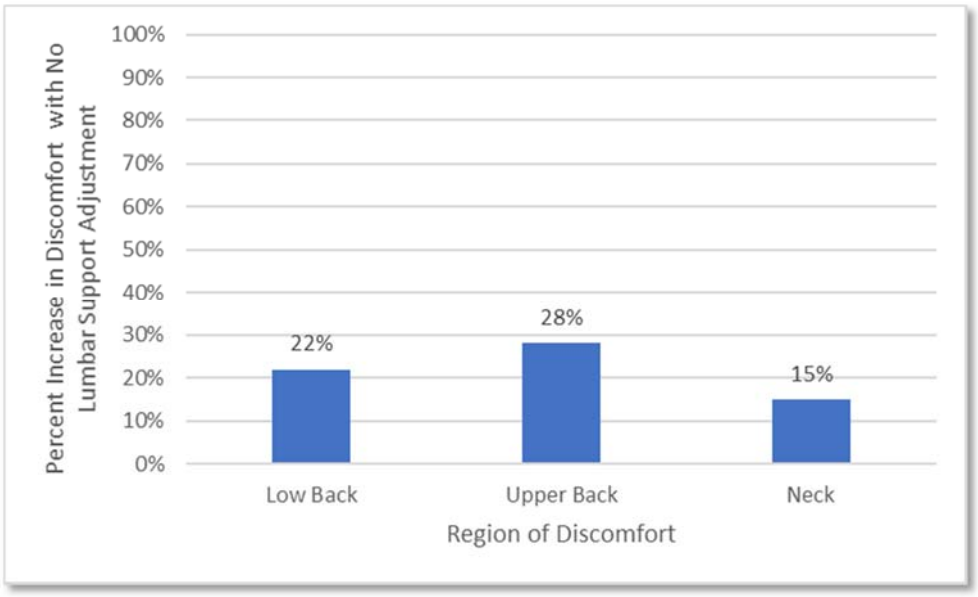

Figure 17: Percent Increase in Discomfort with No Lumbar Support Adjustment vs. Region of Discomfort

These figures demonstrate that having lumbar support available significantly influences the low back and upper back *(p<.05),* but has a lesser impact on the neck. However, proper setup of the chair demonstrates an even greater significance. Figure 18 depicts the percent increase in discomfort is more significant when the employee reports that his/her chair does not properly support the low back.

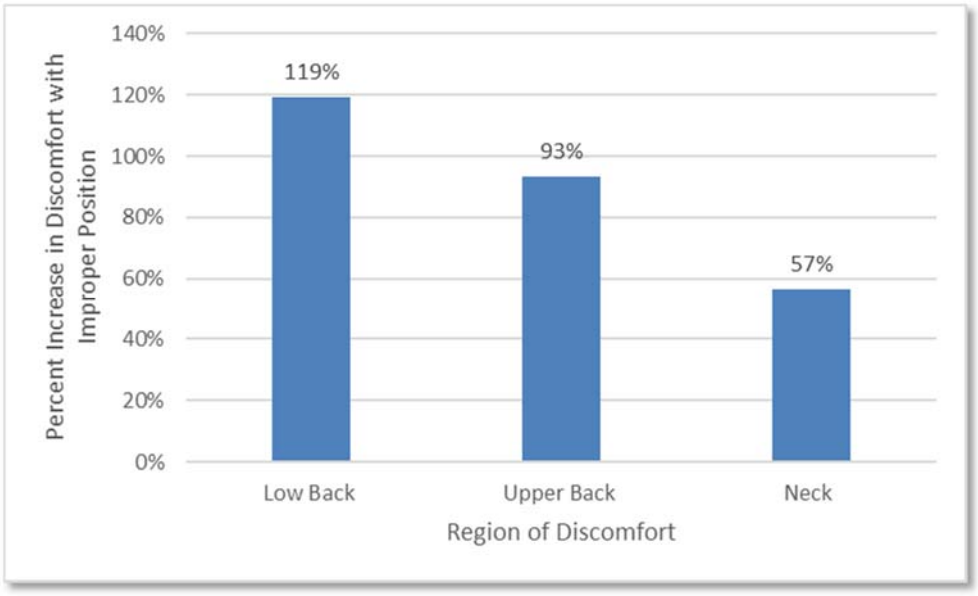

Figure 18: Percent Increase in Discomfort with Improper Positioning vs. Region of Discomfort

Tilt lock is a feature used to lock the chair's back rest in a specific position to allow the employee to change the angle of the hips/thighs to unload the spine by reclining in the chair. Fifty-eight percent of employees in this survey have this feature available to them on their chair. If the feature is effective, it will help to reduce discomfort throughout the spine by allowing the employee to change positions. Figure 19 demonstrates the effect a chair having tilt lock available has on all areas of the spine. Although there is a positive effect throughout the spine, only the upper back demonstrates a significant change with a *p*-value less than .05.

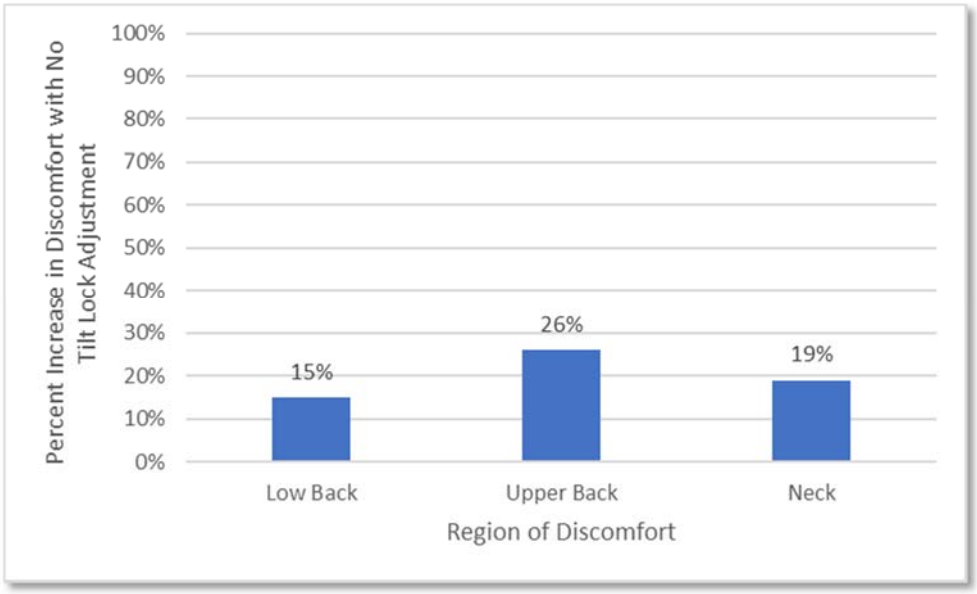

Figure 19: Percent Increase in Discomfort with No Tilt Lock Adjustment vs. Region of Discomfort

Unlike the other adjustments studied, there are no specific questions on our survey that gives us information on an employee's understanding and proper use of the tilt lock adjustment.

Arm rest height adjustability is another common feature with office chairs. Seventy-seven percent of employees in our data set have this feature available to them. Properly adjusted arm rest height will support the upper extremity and therefore relieve stress from the neck and upper back. Figure 20 demonstrates the impact adjustable-height arm rests have on the upper back, neck, and upper extremity.

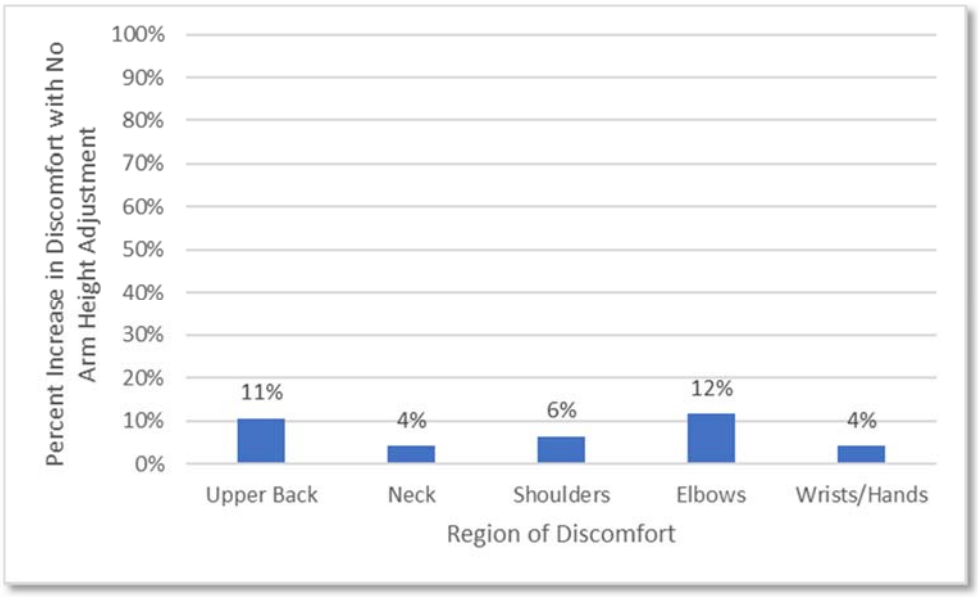

Figure 20: Percent Increase in Discomfort with No Arm Height Adjustment vs. Region of Discomfort

The figure above demonstrates that the availability of arm rest height adjustment plays an insignificant role in discomfort in employees with the highest increase seen in the upper back at 11% and elbow at 12%. However, we see a much more significant effect if the arm rests are not set up to support the employees' arms. Figure 21 demonstrates a significant effect on all regions of the upper extremity, with discomfort in the elbow demonstrating the greatest effect. This reinforces the importance of proper support for the upper extremity in an office setting.

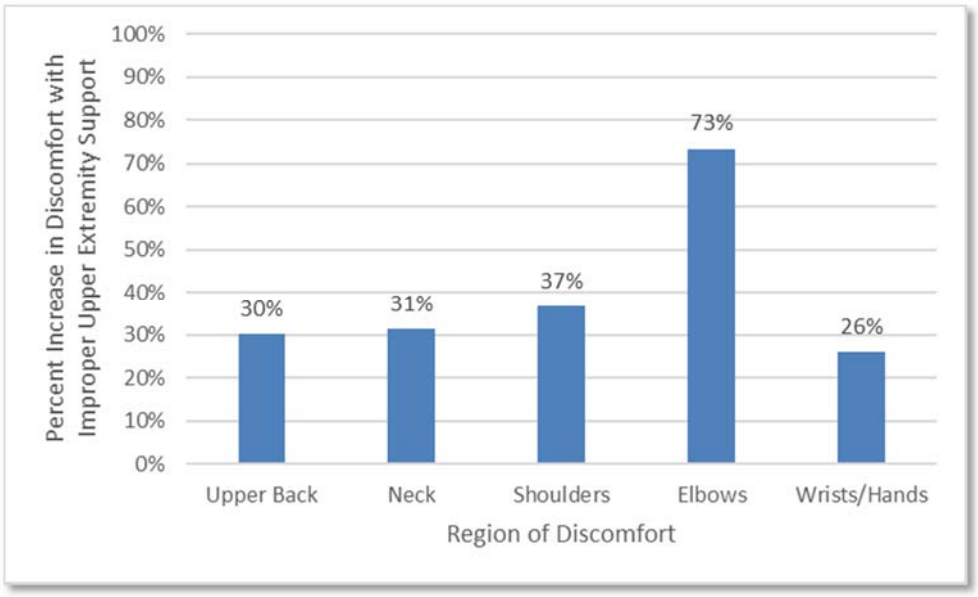

Figure 21: Percent Increase in Discomfort with Improper Upper Extremity Support vs. Region of Discomfort

Arm rest width adjustability has a similar effect as the height adjustment, addressing the potential need for smaller-framed employees. By bringing the arm rests directly beside the body, it eliminates the need to abduct the shoulders to use the armrests. This feature is less prevalent, found in only 28% of the employees' chairs in our data set.

Figure 22 demonstrates that there is no significant effect of the availability of arm width adjustment. The upper back, elbow, wrist and hand demonstrate the greatest differences, but they are not significant.

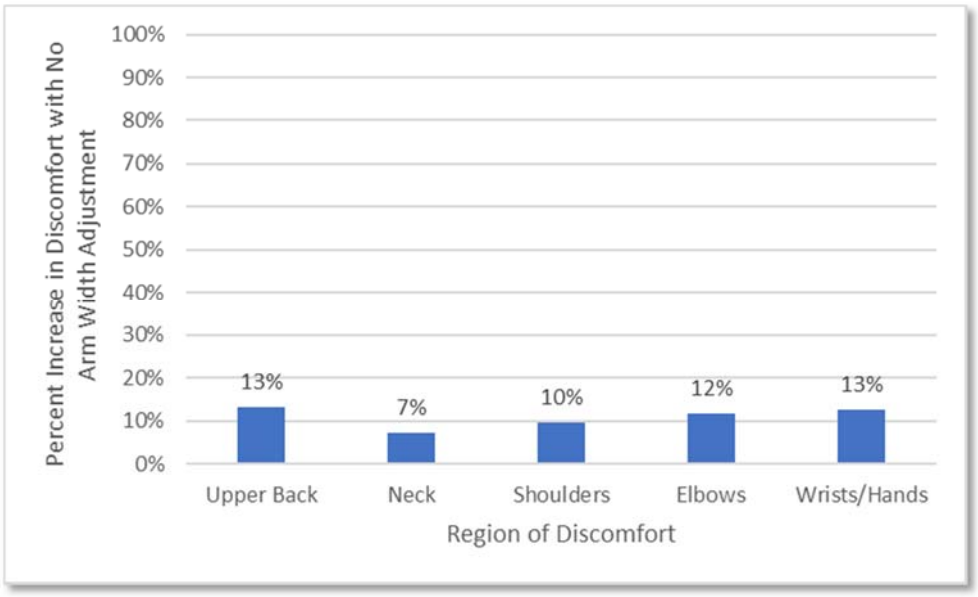

Figure 22: Percent Increase in Discomfort with No Arm Width Adjustment vs. Region of Discomfort

As was seen with the arm rest height, the width adjustment itself does not have a strong effect on discomfort. It is, however, an additional tool to help support the upper extremity. If set up correctly, arm rest width can help decrease the discomfort in the upper back, neck and upper extremity by providing proper upper extremity support, resulting in a significant decrease in discomfort throughout the upper back, neck and upper extremity, especially in the elbow (Figure 23).

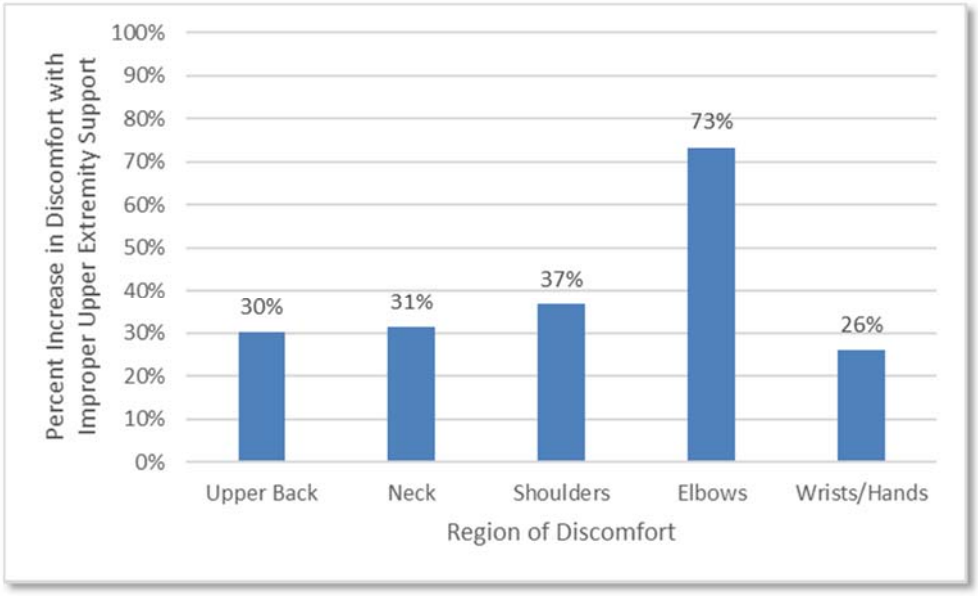

Figure 23: Percent Increase in Discomfort with Improper Upper Extremity Support vs. Region of Discomfort

Effects of Chair Adjustments on Productivity

When a chair is properly adjusted for an employee, it provides support for the spine through lumbar support, seat height and depth adjustments and support for the upper extremity through the arm rest height and width adjustments. Figure 24 demonstrates the effect of availability of chair adjustments on productivity. As seen in the data below, there is minimal effect with no specific chair adjustment demonstrating significant change *(p>.05)*.

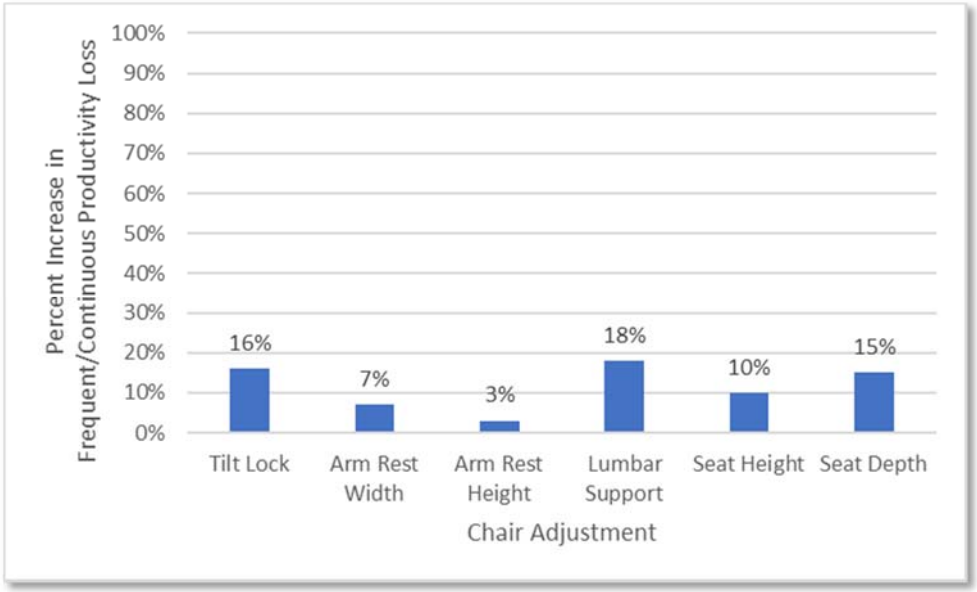

Figure 24: Percent Increase in Frequent/Continuous Productivity Loss vs. Availability of Chair Adjustment

However, when an employee lacks the proper support, there is a significant loss of productivity seen in multiple areas. Figure 25 compares the increase in employee report of frequent to continuous productivity loss when they are lacking proper support from their chair. This data reinforces the importance of lumbar support.

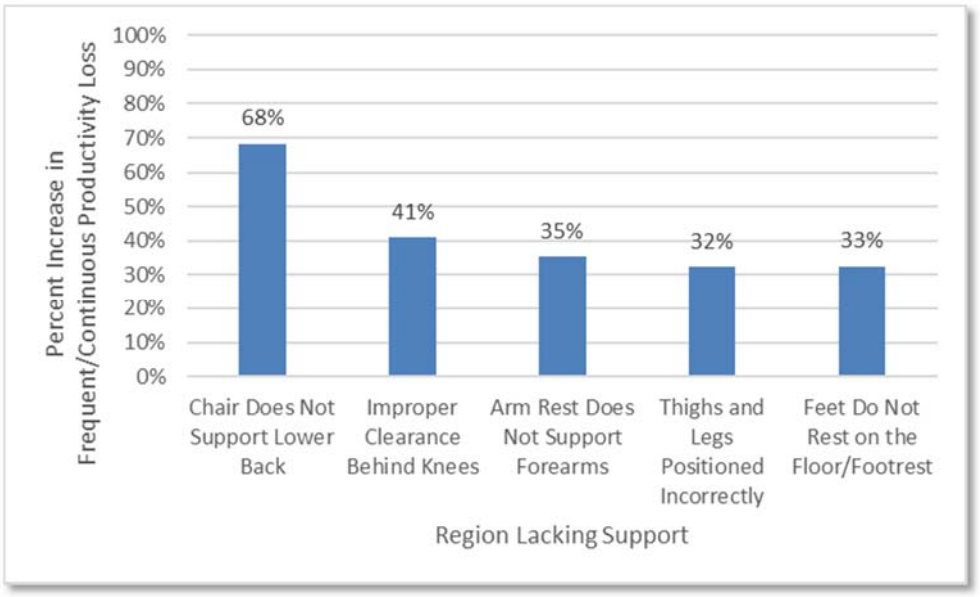

Figure 25: Percent Increase in Frequent/Continuous Productivity Loss vs. Availability of Chair Adjustment

Data Summary:

Influence of Chair Adjustments on Discomfort and Productivity
Lack of proper support is associated with greater discomfort and productivity loss. The availability of most chair adjustments alone does not provide employees with significant decrease in overall discomfort or affect productivity.

The highest increase in productivity loss and level of discomfort are seen with employees who do not have proper back support. There is a 119% increase in level of low back discomfort and a 68% increase in productivity loss when the lower back is not supported properly in the employee's chair. Lumbar support is also the only chair adjustment that by its availability alone has a significant effect on discomfort and productivity.

Lacking upper extremity support through either the arm rest height or width also has a significant effect on upper extremity discomfort, especially seen in the elbow (73% increase). Although it also has a significant effect on productivity, it is only about half of that of the lumbar support.

Comparison to published data
This data agrees with published reports supporting the need for education along with ergonomic adaptability. Robertson et al. found a significant link between decreased discomfort and employee postures. The group that had changes in the work place and education on proper positioning improved significantly more than those with just the changes to the work place[2]. The published reports also support the need for lumbar support in the office chair. De Carvalho et al. found

that the tilt lock in addition to the lumbar support was significant in decreasing the stress on the low back. Although prolonged sitting can lead to injury to the lumbar spine, proper use of tilt lock and lumbar support allow improved posture of the spine[3].

Impact on Approach:
The adjustability of the office chair plays a major role in properly supporting the employee. However, having the adjustments is not enough. Employees must be educated on the adjustments that are available to them on their chair and how to use them to appropriately support their body. Specific attention should be placed on lumbar support and support of the upper extremity to decrease discomfort and the loss of productivity.

Type of Computer

In the questionnaire completed by the employee, there is a choice for type of computer with the options of desktop, laptop, and tablet. Of these, the overwhelming majority of workers (74%) use a desktop, with 26% using a laptop. Only a total of 11 employees reported using a tablet. A follow-up question for the laptop users was if an external monitor, mouse and keypad are used. Of the laptop users; 92% used an external monitor, 90% used an external mouse, and 89% used an external keypad. When external devices such as these are used, it allows the laptop to work essentially as a desktop computer. This leaves less than 3% of the population of this data set using laptop computers or tablets. There is therefore insufficient data to make comparisons within the data set for discomfort or productivity.

Data Summary:

Comparison to published data
Upon review of the current research in office ergonomics trends, there are multiple sources supporting this shift to external devices to decrease discomfort. Farias Zuniga et al. found that the use of external dual monitors significantly decreases neck muscular activity, which in turn decreases fatigue and discomfort in the neck[3]. Werth et al. also found that there was significantly increased flexion of the neck when using a laptop computer compared to the desktop computer[4]. This places unnecessary stress on the neck and upper back.

Impact on Approach:
There is a continued shift moving toward use of external devices to decrease stressors of using a laptop computer. The external devices should therefore set up the laptop equivalent to a desktop computer. When performing an office ergonomic assessment on an individual using a laptop, education should be given on the devices that are available to decrease the stressors to the neck and properly set up the work station.

Keyboard and Mouse Height

The findings on keyboard and mouse height in the original paper were that more employees were using the desk top (69%) than were using a keyboard tray (31%) for positioning the keyboard and mouse. Our current data finds there is an even greater discrepancy with only 19% of employees currently using a keyboard tray. The data sets from both papers also are in agreement that reports of discomfort were more dependent on the position than the device used to get it there. Figure 26 demonstrates that there is no significant difference in upper extremity, neck or upper back discomfort between the use of desk top vs. keyboard tray.

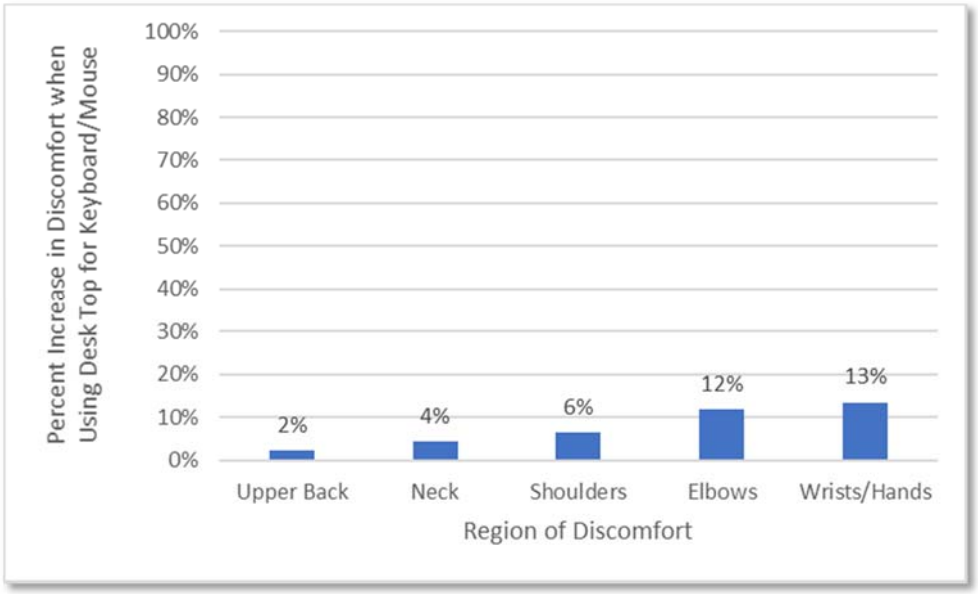

Figure 26: Percent Increase in Discomfort when Using Desk Top for Keyboard/Mouse vs. Region of Discomfort

As was discussed in the original paper, the increase in discomfort is seen when the employee is not set up properly at their work station. Figures 27-32 demonstrate the significant increase in discomfort with poorly set up keyboard and mouse.

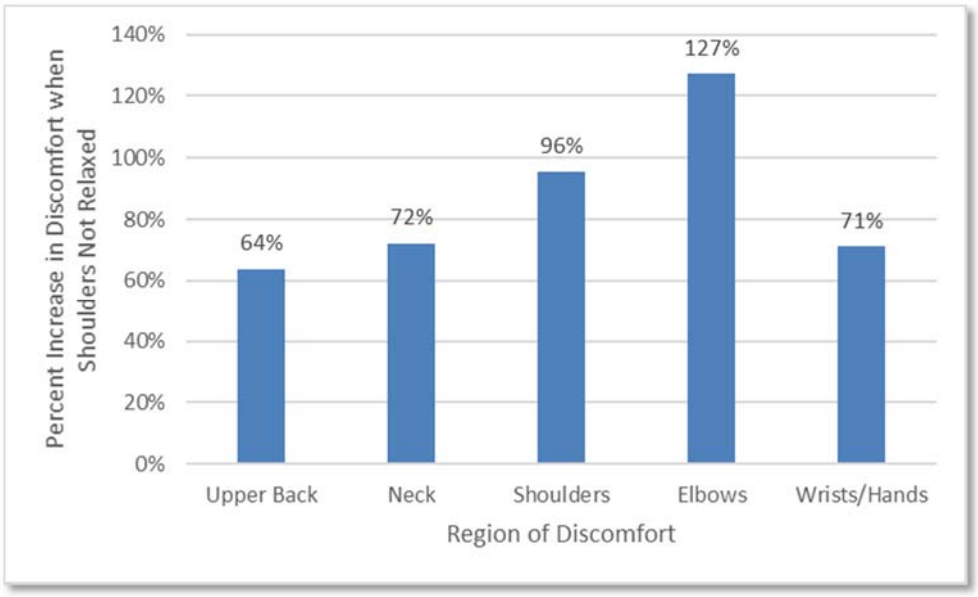

Figure 27: Percent Increase in Discomfort when Shoulders Not Relaxed vs. Region of Discomfort

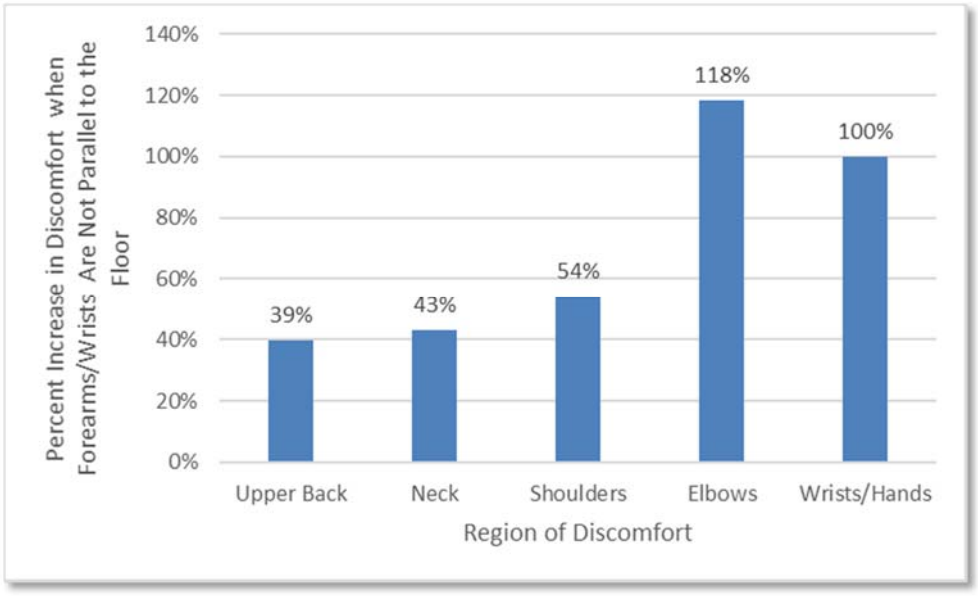

Figure 28: Percent Increase in Discomfort when Forearms/Wrists are Not Parallel to the Floor vs. Region of Discomfort

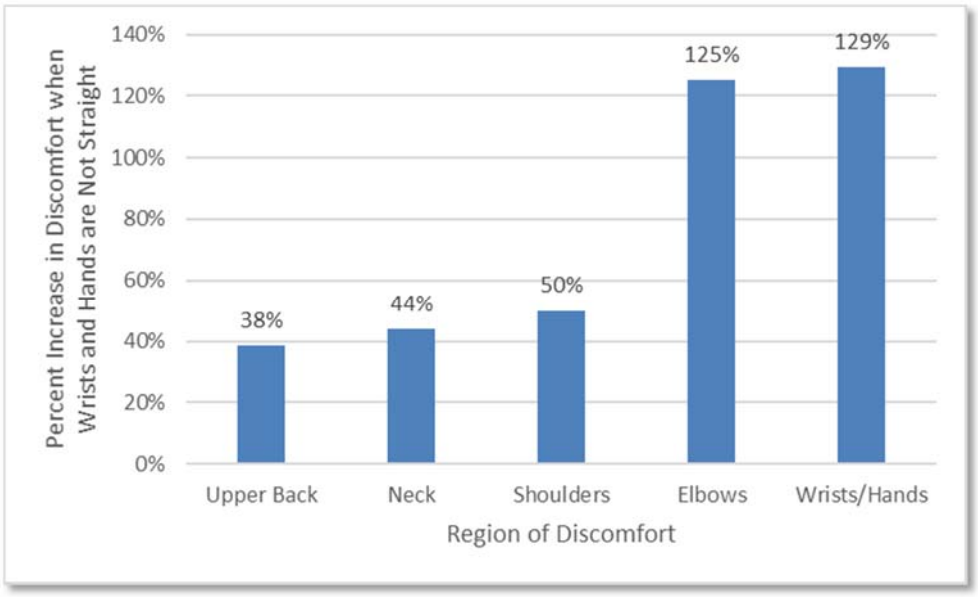

Figure 29: Percent Increase in Discomfort when Wrists and Hands are Not Straight vs. Region of Discomfort

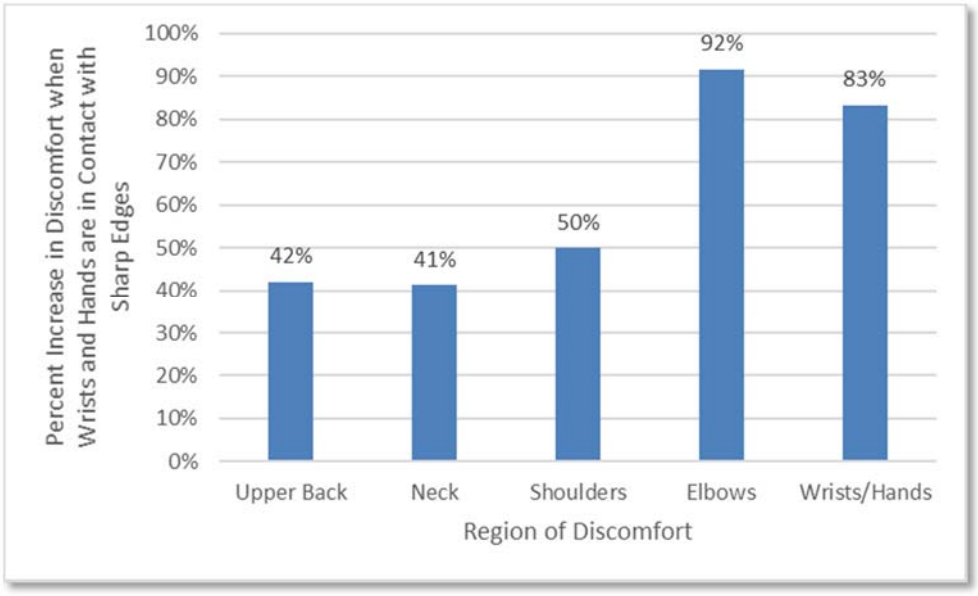

Figure 30: Percent Increase in Discomfort when Wrist and Hands are in Contact with Sharp Edges vs. Region of Discomfort

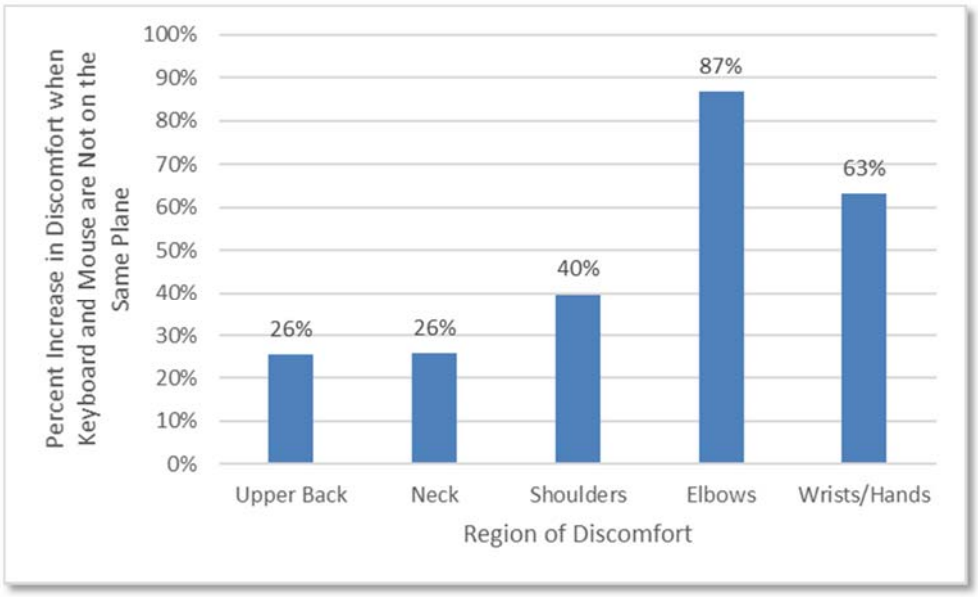

Figure 31: Percent Increase in Discomfort when Keyboard and Mouse are Not on the Same Plane vs. Region of Discomfort

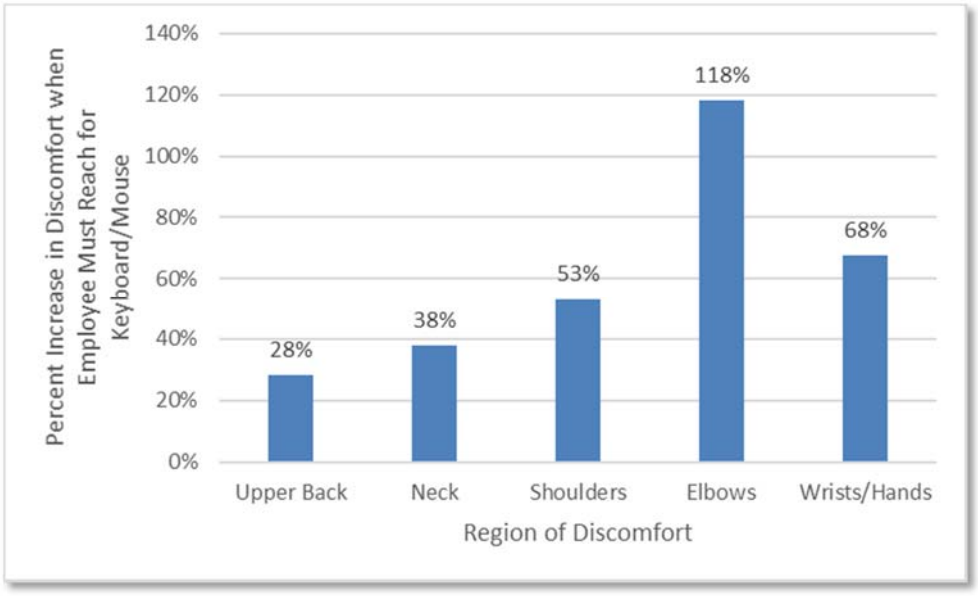

Figure 32: Percent Increase in Discomfort when Employee Must Reach for Keyboard/Mouse vs. Region of Discomfort

The current data set supports our previous findings that improper keyboard and mouse height place more stress throughout the upper extremity and in the neck and upper back. In all but one instance, the elbow is the most affected body part with the wrist and hand considerably affected as well. Figure 33 demonstrates the average increase throughout the upper back, neck and upper extremity for each incidence of poor keyboard and mouse setup.

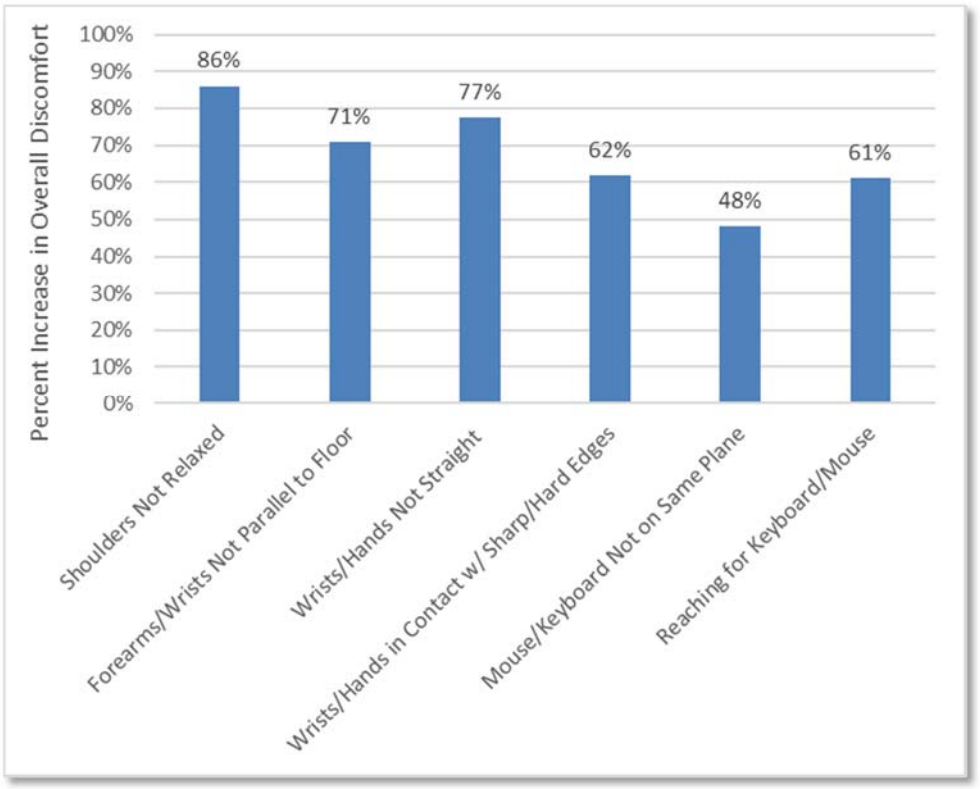

Figure 33: Percent Increase in Overall Discomfort vs. Poor Positioning

Effect of Keyboard/Mouse Position on Productivity

Figure 34 demonstrates the effect on productivity of having a keyboard tray in comparison to using on the desk top. Although there is a small difference noted (1%), it is not a significant change. The effect of poor keyboard and mouse position, regardless of the type of surface, has a much more significant effect on productivity. There is not one specific type of poor positioning that causes a greater loss of productivity than the others. However, each improper setup causes significant productivity loss with close to half of the employees reporting frequent to continuous productivity loss (Figure 35).

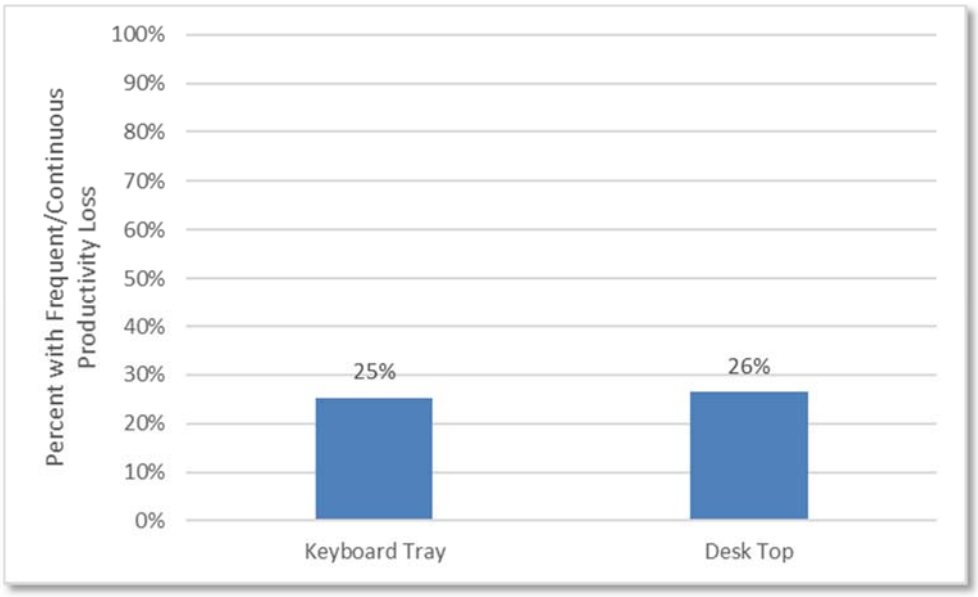

Figure 34: Percent with Frequent/Continuous Productivity Loss vs. Keyboard Tray/Desk Top Use

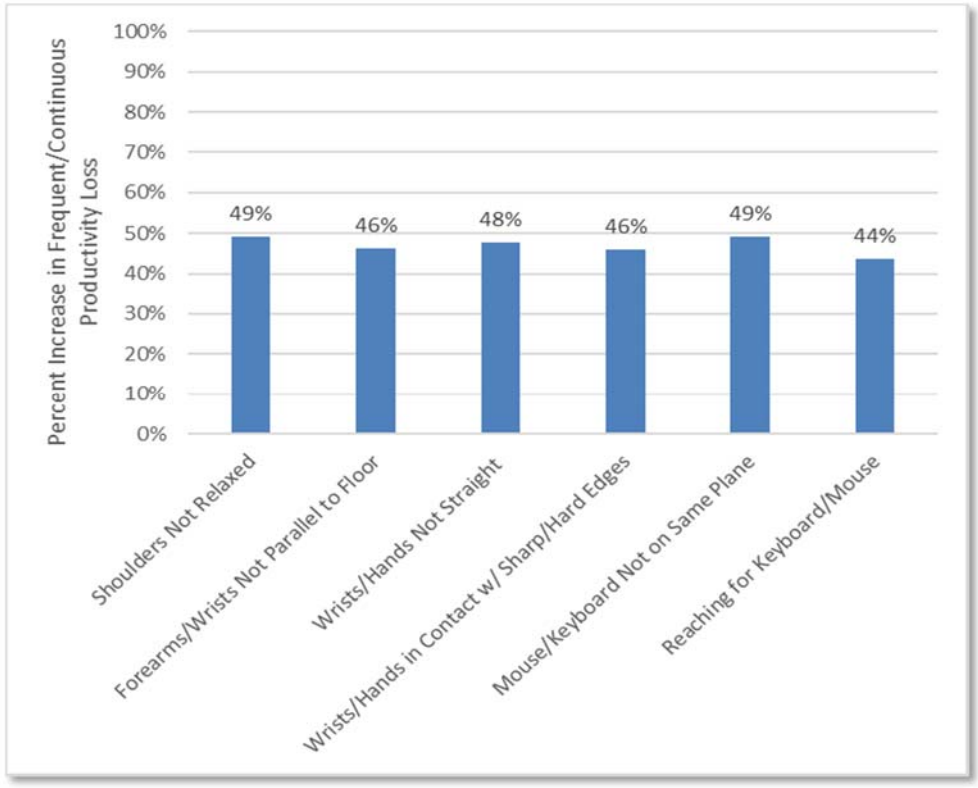

Figure 35: Percent Increase with Frequent/Continuous Productivity Loss vs. Poor Positioning

Data Summary:

Influence of Keyboard/Mouse Height on Discomfort and Productivity
There is a significant increase in overall discomfort when comparing employees with and without proper keyboard and mouse height, but no significant difference in use of keyboard tray or desk top. The elbow and wrist/hand demonstrated the most significant overall negative effect. Productivity loss is generally not affected by use of either a keyboard tray or the desk top. However, improper position caused an approximate 50% loss in productivity at a frequent or continuous level when compared to the same in employees with proper setup.

Comparison to published data
In their 2007 article in *Ergonomics,* Kotani et al. found that the placement of the keyboard and mouse play a major role in the amount of muscle activity in the forearm and shoulder. There was also a significant change in the wrist positioning that places stress on the joint[8]. These factors place an individual at a higher risk for discomfort.

Impact on Approach:
Emphasis should be placed on ergonomic modifications to allow proper positioning in the upper extremity while typing. Employees should be educated in proper use of equipment available and setup of keyboard and mouse. Setup that allows shoulders to be relaxed, the arm to be supported without sharp or hard edges, and allowing the wrist and hand to stay neutral should be an integral part of the solutions for office ergonomics programs.

Monitor

As an addition to the study, use of the monitor was analyzed. The employee impact of monitor use involved many factors.

Screen glare has been a significant concern in the past. However as was discussed in the original paper, the change from CRT to LCD screens greatly decreased the glare because of the matte finish. Only 10% of the employees in this data set report screen glare as an issue. This is down from 20% in the original paper in 2008. Although glare is not as frequent an issue as it was before the LCD screen was more prominent, there is a 195% increase in intensity of eyestrain when there is reported glare on the monitor. With this level of increase, it is imperative that the glare is addressed in an office assessment.

Eye strain was additionally seen in employees requiring multi-lens glasses in the original paper. Employees with trifocal lenses were found to have significant increases in eye strain as well as neck discomfort. Our updated data set does not demonstrate the same findings. There was only a 9% increase in eye strain and 16% increase in neck discomfort seen in employees wearing trifocal lenses and

an even smaller insignificant change in those wearing bifocal glasses. One possible explanation for this change would be the increase in progressive lens worn by computer users. These lenses improve the ability to see at all distances, including at arm's length for computer use.

Finally monitor height, if it is centered, and distance away from the employee play an important role in keeping the head in an upright position. Monitor position was investigated on three aspects and their effect on eye strain, head/neck discomfort and upper back discomfort. Figures 35-37 demonstrate the effect of monitor height, if it is positioned in the center, and distance away from the employee.

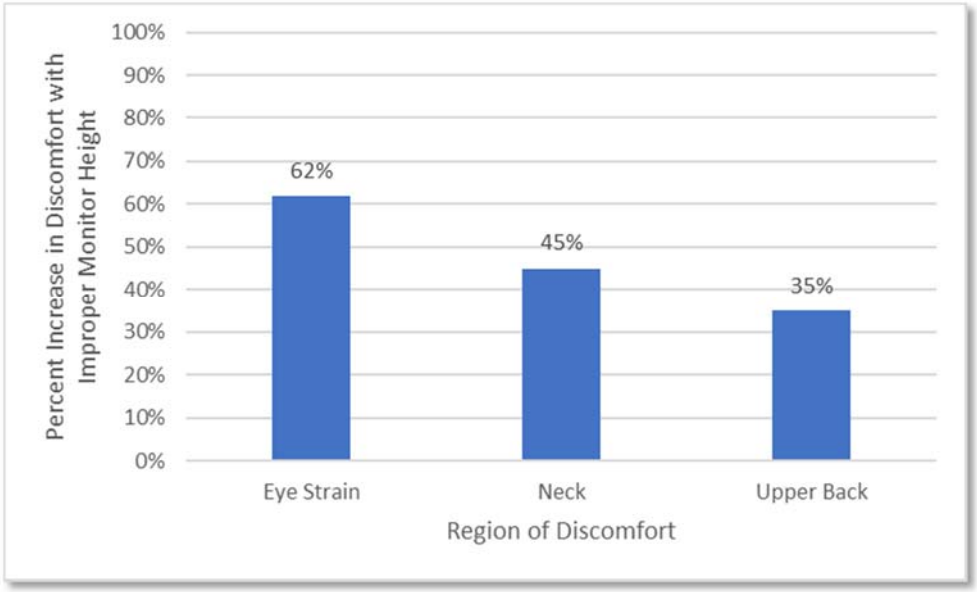

Figure 35: Percent Increase in Discomfort with Improper Monitor Height vs. Region on Discomfort

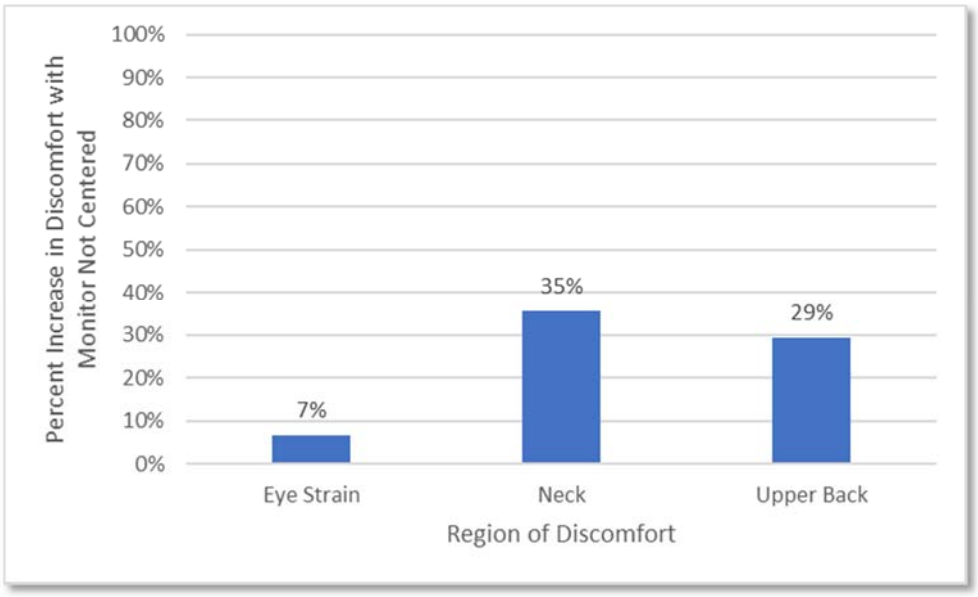

Figure 36: Percent Increase in Discomfort with Monitor Not Centered vs. Region on Discomfort

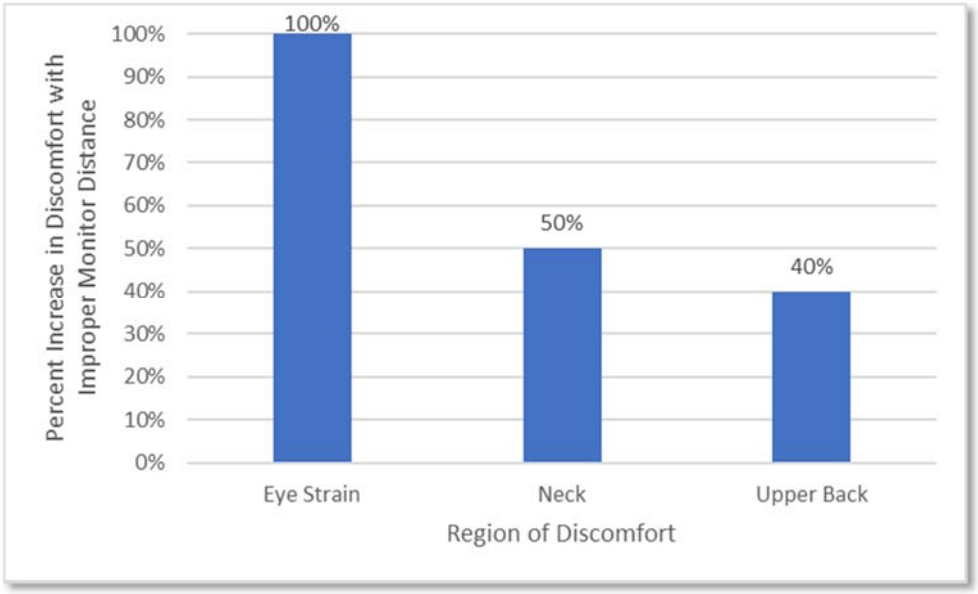

Figure 37: Percent Increase in Discomfort with Improper Monitor Distance vs. Region on Discomfort

Each incorrect positioning of the monitor causes a significant effect on discomfort. The only exception to this is monitor centering does not affect eye strain.

Effect of Monitor Position on Productivity
Figure 38 depicts the effect of the three monitor positions' productivity loss. Each improper setup causes significant productivity loss with close to half of the employees reporting frequent to continuous productivity loss.

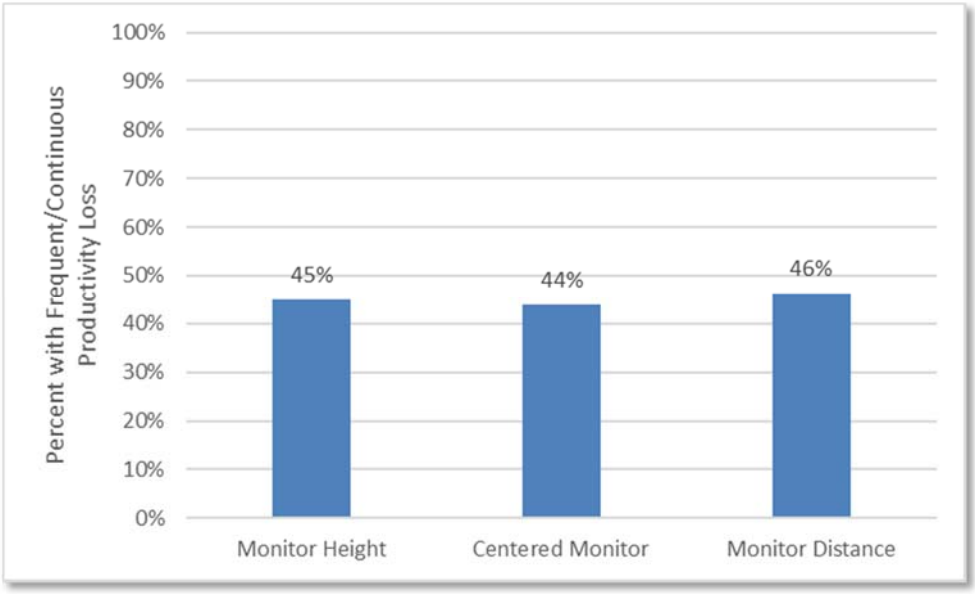

Figure 38: Percent with Frequent/Continuous Productivity Loss vs. Improper Monitor Position

Data Summary:

Influence of Monitor Position on Discomfort and Productivity
Overall there is a significant increase in eye strain and discomfort in the neck and upper back when the monitor is not properly adjusted. Improper monitor height, centering, and distance from the employee increase discomfort as well as negatively affect productivity in approximately 50% of the employees.

Comparison to published data
Jaschinski et al. found that proper positioning of the monitor allows a more vertical gaze and avoids extension of the neck. This decreases the muscular activity in the neck musculature and will decrease fatigue that leads to discomfort[9].

Impact on Approach:
Emphasis should be placed on properly setting up the employee's monitor to allow the head and neck to be upright and in a neutral position. Monitor height, centering and distance from employee all play important roles in achieving this. Additionally, although monitors that produce glare are less

common, complaints of glare should be addressed to decrease eye strain of employees.

Adjustable Height Work Surface

As an addition to the study, use of an adjustable height work surface was analyzed. There is currently substantial growth in the use of adjustable height work surfaces in the office setting. Sit-stand desk adaptors are making this feature more affordable. There was not sufficient data in the original paper for this feature to be sufficiently reviewed. However, in the current data set the number of sit-stand workstations has increased to approximately 20% of the employees who completed the survey.

Figure 39 demonstrates the effect an adjustable work surface has on low back and lower extremity discomfort. In this product, decrease in discomfort is used as it is compared to the normal standard desk. There was a decrease of 24% in low back discomfort in employees who use an adjustable work surface. Other body parts did not show significant difference in the use of this feature. There has been concern raised in the possibility of ankle and foot pain with the increase in standing, but as seen in Figure 39 there is no significant difference.

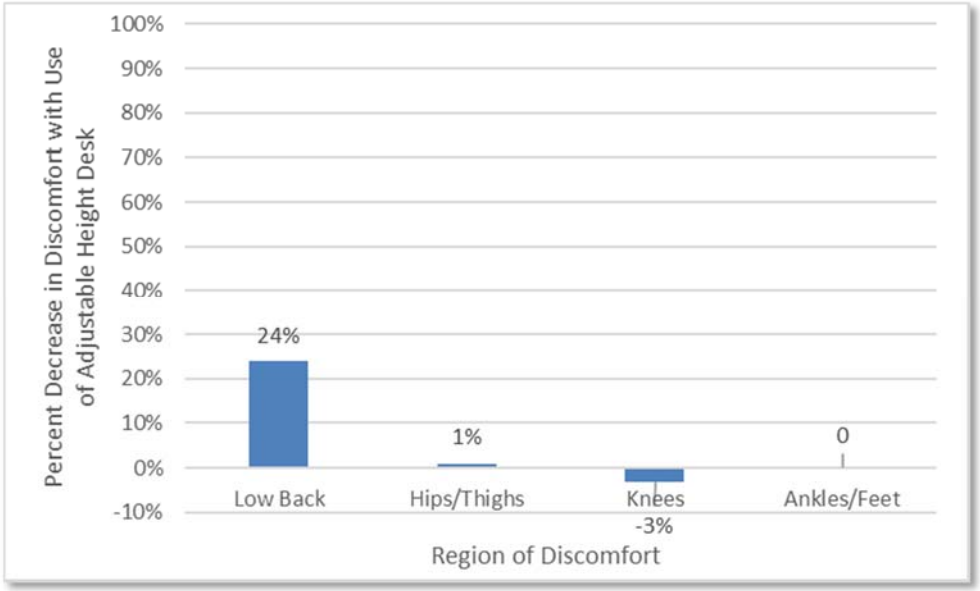

Figure 39: Percent Decrease in Discomfort with Use of Adjustable Height Desk vs. Region of Discomfort

Effect of Adjustable Work Height on Productivity

Although there is a higher number of employees who work on a stable surface, the data suggests that there is a decrease in employees reporting frequent to continuous loss of productivity when using an adjustable work height. Figure 40 demonstrates approximately twice as many employees in this category report

frequent to continuous loss of productivity because of their discomfort when using a stable work height.

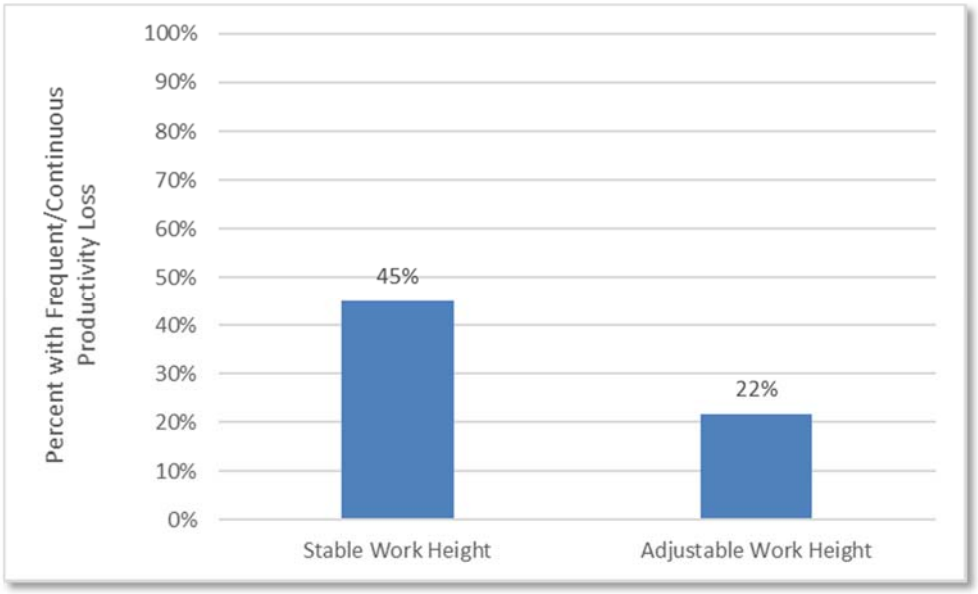

Figure 40: Percent with Frequent/Continuous Productivity Loss vs. Work Height Adjustability

Data Summary:

Influence of Work Height Adjustability on Discomfort and Productivity
There continues to be limited data on this subject, but as the availability of this feature increases, as will our ability to analyze its significance in the office setting. With the data available, there is evidence that with the ability of an employee to adjust the height of his/her work surface to allow sitting/standing, there is a decrease in overall low back pain and reports of loss of productivity.

Comparison to published data
Across the research reviewed, the literature points to the greatest benefit of the adjustable height work station in an office setting being the decrease in sitting time. Li et al. agrees with this finding. In her 2017 article in the *Journal of Occupational and Environmental Medicine,* there was a decrease in sitting time on average of 113 minutes per 8-hour work day with use of a sit-stand desk.[10] There are not significant findings on effects on region of discomfort, but decreasing time in a sitting position has been shown to decrease the overall stress on the low back.

Impact on Approach:

Proper use of an adjustable work height office setup can have positive effects on productivity and low back discomfort. Along with a properly adjusted chair that supports the lumbar spine, an adjustable work height is a possible tool that can be used to help decrease the level of low back discomfort in an office setting.

CONCLUSION

In this update, chair adjustment, computer type, keyboard/mouse position, and monitor position were reanalyzed through an updated larger data set to determine the effect they have on discomfort in employees. In addition, this study analyzes the effects of using an adjustable work surface. The data analysis was expanded to include the effect that product options have on productivity loss. Recommendations based on the findings are summarized below.

Discomfort Control

The data has demonstrated that we must look not only at the effects of the adjustments alone, but also with the appropriate training to set them up properly. Figure 41 gives a breakdown of the product options that were reviewed and their effect on total discomfort of an employee. The chart demonstrates that lumbar support (27% reduction) has the greatest effect on overall discomfort. All others have significantly less effect.

Product Option	Average Total Discomfort Without	Average Total Discomfort With	Average Total Discomfort Reduction
Seat Height	17.3	15.7	10%
Seat Depth	15.8	13.8	14%
Lumbar Support	16.7	13.1	27%
Tilt Lock	16.4	14.0	17%
Arm Height	17.6	15.9	11%
Arm Width	16.1	14.8	9%
Keyboard Tray	13.4	13.8	-3%
Adjustable Work Surface	14.3	14.2	1%

Figure 41: Effect of Product Options on Discomfort

This data demonstrates a less than desired effect than one would hope when providing employees with products to help decrease their discomfort level. Figure 42 explores the effect we can have on employee discomfort if they are educated in proper setup of the products. Here we see a much more dramatic reduction in overall average total discomfort.

Education/Training	Average Total Discomfort with Poor Position	Average Total Discomfort with Proper Position	Average Total Discomfort Reduction
Chair supports lower back	19.6	11.1	77%
No reaching for keying or mousing	19.8	11.8	68%
Shoulders and upper arms relaxed	20.3	12.2	66%
Mouse / keyboard same plane	24.2	14.8	64%
Display is free of glare	23.1	14.2	63%
Wrists and hands are reasonably straight	20.7	12.8	62%
Head and neck are about upright	19.1	12.2	57%
Forearms and wrists are about parallel to the floor	19.7	12.6	56%
Wrist and hands are free of sharp or hard edges	19.4	12.5	55%
Arm rest supports forearms	20.8	13.8	51%
Feet rest on the floor or stable footrest	20.2	13.5	50%
Proper clearance behind knees	20.3	13.8	47%
Thighs and lower legs positioned correctly	18.5	12.6	47%
Trunk is perpendicular to floor	18.2	12.4	47%
Display is arm's length away	18.9	13.9	36%
Adequate space and clearance for legs	19.4	14.5	34%
Monitor is at correct height	18.5	13.9	33%
Monitor directly in front of user	13.1	11.6	13%

Figure 42: Education/Training Effect on Discomfort

The overall effect on discomfort through training and education is significantly higher (p<.05) than through the products alone. The average reduction for the products is 11% whereas in the education and training we see an average of 51%. In fact, all education/training topics have a higher average reduction in discomfort than the products except for positioning the monitor in front of the user.

In both groupings the data demonstrates the importance on the lumbar support. Having proper support as well as just having the support available on the product are the highest rated in each category.

In Figure 43, the data is further broken down into the effect on specific body regions. Throughout the paper we have looked at the increase in discomfort that is seen when products or training are not available. In this chart we break down where we see the greatest decrease in discomfort for each region of the body. This chart can be used to help guide decision making for which products or where the education/training should take place to most help the employee.

Body Part	Product Solution	Decrease in Discomfort	Training Solution	Decrease in Discomfort
Eyes	NA	NA	*Decrease Glare*	67%
Head/Neck	*Lumbar Support*	15%	*Proper Monitor Height*	31%
Upper Back	*Lumbar Support*	24%	*Proper Lumbar Support*	48%
Shoulders	*Adj Height Arm Rest*	6%	*No Reaching for Keyboard/Mouse*	35%
Elbows	*Adj Height Arm Rest*	8%	*No Reaching for Keyboard/Mouse*	54%
Wrists/Hands	*Adj Height Arm Rest*	5%	*Forearms and Wrists Straight*	55%
Low Back	*Lumbar Support*	22%	*Proper Lumbar Support*	52%
Hips/Thighs	*Seat Depth*	15%	*Feet Supported Flat on Ground/Foot Stool*	28%
Knees	*Seat Depth*	13%	*Proper Clearance Behind Knees*	42%
Ankles/Feet	*Seat Height*	33%	*Feet Supported Flat on Ground/Foot Stool*	56%

Figure 43: Most Effective Product and Training Solution for Each Body Region

We can again see the importance of training for employees to help decrease reports of discomfort.

Productivity Loss Control

As was seen in the comparison of discomfort control, productivity also is more affected by training/education than the products themselves. Figure 44 describes product availability to decrease or avoid productivity loss in employees.

Product Option	Average Productivity Loss Without	Average Productivity Loss With	Productivity Loss Avoidance
Seat Height	42%	38%	11%
Seat Depth	41%	35%	18%
Lumbar Support	42%	35%	22%
Tilt Lock	42%	36%	19%
Arm Height	40%	39%	3%
Arm Width	40%	38%	7%
Keyboard Tray	25%	26%	-4%
Adjustable Work Surface	45%	22%	105%

Figure 44: Product Option Effect on Productivity

The only significant change that we see with product option availability is with the adjustable work surface (105%). This data demonstrates that having an adjustable work surface can have a significant effect on decreasing productivity loss, but others do not have a significant effect.

Figure 45 gives similar data for education/training. There is not as great an effect on productivity as there is with discomfort, but there continues to be significant decreases especially seen in centering the monitor, providing lumbar support, and decreasing glare on the monitor.

Education/Training	Average Productivity Loss with Poor Position	Average Productivity Loss with Correct Position	Proper Postion Productivity Loss Avoidance
Monitor directly in front of user	44%	24%	80%
Chair supports lower back	49%	29%	68%
Display is free of glare	57%	37%	53%
Proper clearance behind knees	51%	36%	41%
Display is arm's length away	46%	34%	36%
Arm rest supports forearms	49%	36%	35%
Wrists and hands are reasonably straight	48%	35%	35%
Shoulders and upper arms relaxed	47%	35%	35%
Feet rest on the floor or stable footrest	48%	36%	33%
Wrists and hands are free of sharp or hard edges	46%	35%	32%
Forearms and wrists are about parallel to the floor	46%	35%	32%
Adequate space and clearance for legs	48%	38%	26%
Monitor is at correct height	45%	37%	22%
Thighs and lower legs positioned correctly	43%	36%	22%
No reaching for keying or mousing	44%	36%	22%
Head and neck are about upright	43%	36%	18%
Trunk is perpendicular to floor	41%	37%	12%

Figure 45: Education/Training Effect on Productivity

Key Impacts on Approach:

- *Using the above charts, practitioners and employers can choose the most effective tools and training for their employees.*
- *Product options should be accompanied with the training and education on how to properly use and set up to allow the greatest effect on decreasing discomfort and reducing productivity loss.*

- *Lumbar support is a significant factor in discomfort and productivity. Priority should be placed on supplying this to employees and providing training for proper setup.*
- *The position of the keyboard and mouse is more important than the product used to achieve this position. Emphasis should be placed on finding the correct positioning and choose if a device such as a keyboard tray is needed.*
- *With the increase in popularity of adjustable work stations, there was sufficient data to address the benefits of this feature. There is a decrease in low back discomfort and responding increase in productivity with employees using the adjustable height feature. It was expected to see an increase in ankle/foot discomfort with the increased amount of standing. However, this was not the case.*

The gathering of data on adjustments and features available to the employee prior to completing an ergonomic office assessment is vital to understanding where emphasis needs to be placed. AtlasOffice™ gives the employee the opportunity to provide this information through an on-line survey before the evaluator begins the assessment. With this information, the provider is better equipped to give a more effective assessment and better solutions.

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