**Proposal of a new equation to define and evaluate maximum desk height in educational contexts.**

**Abstract**

This research analyses differences in kinematics, electromyography (EMG), task performance, personal preference, and discomfort between two desk height conditions: one based on the principles of Chaffin and Anderson and the other using a new equation, developed and proposed through this work. A quasi-experimental study with 34 participants was conducted. Participants performed tasks on both desk height conditions, with data collected on shoulder kinematics and muscle activity using motion capture and surface EMG, respectively. Performance metrics varied based on task type, while preference and discomfort were assessed through surveys and visual analog scales, respectively. Findings suggest no significant differences between the two setups in safe shoulder kinematics, while EMG results showed consistent safe muscle activity patterns for both setups. Performance metrics did not significantly differ between conditions. Preference analysis revealed no significant difference, while discomfort levels were comparable between conditions. In conclusion, it can be determined that the new equation for maximum desk height can be utilized while upholding health standards, being better suited to the practicalities found in educational settings.

**Keywords:** Seat to Desk height, design, anthropometry

**1. Introduction**

The current educational model has determined that students (and workers) are faced with completing long shifts (6 or 8 hours a day) in a seated position in classrooms (or offices) around the world (Gligorović et al., 2018; Kett and Sichting, 2020) that forces a static, restricted, and uncomfortable posture, which over time can be harmful to health. Castellucci et al (2017) found that a change in school furniture dimensions (better fit or match) resulted in an improvement in posture, muscle activity and a reduction in discomfort/pain. Students are usually exposed to furniture with fixed dimensions, which makes it almost impossible to adjust to the anthropometric changes they suffer during their school life. The main reason for not having height adjustable school furniture is mainly due to viability issues related to increased costs and maintenance requirements, both of great concern for the school system in general. For the same reasons, international standards use grading/scalability techniques which are based on the use of different equations to define sizes (e.g. clothing S, M, L, XL, XXL) (de Bruin and Castellucci, 2022). These equations are widely used worldwide, specifically prescribing school furniture dimensions (standards) or to evaluate the level of match/mismatch between anthropometric measures (Cantin et al., 2019; Carneiro et al., 2017; Castellucci et al., 2021; Kahya, 2019; Macedo et al., 2015; Obinna et al., 2021; Parvez et al., 2019; van Niekerk et al., 2013; Yanto et al., 2017). Regarding desk height or seat to desk height, there are different equations to define this dimension (Castellucci et al., 2015). The most used equation is based on Chaffin and Anderson’s principles (1991) and was used for the first time in the context of school furniture by Parcells et al. (1999) and is continued to be used by different authors (e.g. Altaboli et al., 2023; Khoshabi et al., 2020; L~~ee et al., 2021~~; Lee and Yun, 2019).

This two-way equation, proposed by Parcells et al. (1999) considered that acceptable elbow resting height (AERH) depends not only on Elbow Height Sitting (EHS), but also on the shoulder flexion and abduction angles. To determine AERH it is necessary to know the Shoulder Height Sitting (SHS) and EHS, since by subtracting these anthropometric measures the Upper Arm Length (U) can be calculated. Shoulder Flexion (θ) and Shoulder Abduction (β) need to also be considered in the following main formula:

Eq. (1)

The equation considering Chaffin and Anderson’s principles (1991) of both acceptable shoulder flexion (angles from 0° to 25°) and shoulder abduction (from 0° to 20°) calculates minimum seat to desk height (DH) using a minimum shoulder flexion and abduction of 0°. For both, the corresponding cosines are 1. Given that the cosines are monotone functions of the angles, the minimum desk height is determined by the EHS. On the other hand, the maximum seat to desk height is calculated by considering the 25° of shoulder flexion and 20° of shoulder abduction, where the corresponding cosines are 0.9063 and 0.9397, respectively. Replacing these values in Eq.1, the equation proposed is:

Eq. (2)

However, it can be very difficult to define a convincing equation or special criteria for desk height. In that regard, Castellucci et al. (2014) showed that the interrelation between seat to desk height and seat to desk clearance can be contradictory, even in ideal conditions. From the data of 2,261 students, the results showed that 37% of the students will use a higher seat to desk height (high mismatch), rather than safely recommended seat to desk height given by the Chaffin and Anderson’s principles (Chaffin and Anderson, 1991). This situation can also be explained by the different values of Elbow height sitting and Tight thickness, where the latter is highly dependent on obesity and its increase in the population (Vio del Rio, 2018).

Considering the bottom to top approach design and evaluation of school furniture should always start with seat height (Castellucci et al., 2015). Secondly, the students need an under-table space that large enough to push the chair underneath it, thus allowing free movement of their legs. There are not many changes that can be made to the seat to desk clearance equations since it is a convenient equation for the determination of space and can be easily applied if the researchers use tight thickness. Moreover, there is not sufficient data available to justify continuing to use the maximum desk height proposed by Parcells et al. (1999). Furthermore, the criteria presented by Chaffin and Anderson (1991) do not take elbow or forearm support into consideration, which could reduce the strain on the shoulder (Slot and Charpentier, 2009). Additionally, some authors suggest that for writing and drawing with forearm or elbow support, the table should be positioned 10 cm above EHS (Kroemer and Grandjean, 1997; Pheasant, 2003). Finally, 30° abduction can be considered a safe posture for the shoulder as elbow/forearm support modifies the shoulder`s biomechanics, shifting the pivot from the shoulder to the elbow, thus reducing the strain on the first (Marras, 2012).

The aim of the current paper is thus to determine the differences in the kinematics, EMG, performance, preference, and discomfort variables during the use of maximum desk height of the equation considering the principles of Chaffin and Anderson (original from 1991) and the new equation based on 30° of abduction and 35° flexion (proposal).

**2. Methods**

The following quasi-experimental repeated measures study was conducted at the Ergonomics and Biomechanics Laboratory in the Faculty of Medicine at Universidad de Valparaíso, Chile. The 34 participants who accomplished the inclusion criteria performed 6 different tasks on 2 desk height conditions. All procedures were conducted following the Declaration of Helsinki and approved by the Bioethics for the Research Board of the Faculty of Medicine at Universidad de Valparaiso – Chile (approval no. 20/2022).

**2.1. Sample**

A sample size calculation was conducted using G\*power for a Two-way ANOVA for repeated measured, 80% power, α 0.05, giving a total sample size of 34 participants. A convenience sample of 34 healthy right-handed participants (16 males and 16 females, aged from 18 to 25 years old) with no history of upper-extremity musculoskeletal disorders were recruited for the study (Table 1).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Women | | Men | |
|  | mean | SD | mean | SD |
| Age (years) | 22.00 | 1.62 | 21.82 | 2.19 |
| Height (cm) | 159.82 | 5.69 | 173.53 | 7.16 |
| Weight (Kg) | 61.75 | 9.36 | 74.69 | 12.85 |

Table 1. Sample characteristics.

**2.2. Independent variable**

The desk height used as the independent variable (original versus proposal) only considered the higher level of desk height and considered the Popliteal height to define seat height.

**Original Desk height:**

**Proposal Desk height:**

Where PH is popliteal height; SC is shoe correction (2cm was considered); EHS, elbow height sitting; DH, desk height; and SHS, shoulder height sitting.

**2.3. Dependent variable**

Dependent variables can be grouped into five categories: kinematics, EMG, performance, preference, and discomfort. Each variable is listed within its category.

***2.3.1. Kinematics.***

Shoulder kinematics were recorded using a motion capture system (Vicon Motion Systems Ltd., Oxford, UK) which can detect the spatial displacement of markers attached to participants’ body landmarks and reconstruct their trajectories (Gómez Echeverry et al., 2018). Data was sampled and captured at 100hz. Nineteen retroreflective markers were placed on anatomical landmarks to determine the shoulder movement following Vicon’s Upper Limb Model (Vicon Motion Systems®, UK). The model calculates the desired output angle using the Euler angles technique. Shoulder flexion and shoulder abduction were considered measured in sexagesimal degrees (°).

***2.3.2. Electromyography.***

Surface EMG (sEMG) signals were recorded using Trigno wireless sensors (Delsys, Inc., Natick, MA, USA) in a multichannel configuration for the right-sided target muscles, sampled at a frequency of 2000hz. Target muscles were the Deltoids, Trapezius, and Serratus, where different portions for each muscle were measured and treated as individual muscles for data capture and analysis purposes. Resulting muscle measured were: Anterior Deltoids, Medial Deltoids, Superior Trapezius, Medial Trapezius, Inferior Trapezius, and Serratus Anterior.

Before placing wireless electromyography sensors, participants' skin was cleaned with disposable tissue paper wet with alcohol to improve double-sided tape adhesion and increase signal capture.

To ease the process of data capture and data comparison between and within subjects, participants were asked to yield the theoretical maximum amplitude of activation during muscle contraction against manual resistance in an Isometric Maximum Voluntary Contraction (iMVC) task. The task consisted of the exertion of maximal effort during an isometric contraction for three seconds, followed by a minute of rest. This action was performed three times. The following variables were considered:

* Average amplitude (%iMVC): the average amplitude of electromyographical activity normalized against the maximal EMG values of iMVC, measured in percentage of activation (%).
* Activity periods: refers to the time each muscle is active during the desired task, calculated after determining a threshold for levels of activity (low, moderate, high, and very high) and inactivity periods, measured in seconds (s).

***2.3.3. Performance.***

Performance was measured using different variables due to the differences in the tasks to be executed. For those tasks that involved writing or reading, performance was measured as the number of words per minute; while for object manipulation tasks, performance was translated into task completion time. Finally, for tasks related to the use of electronic devices such as PCs or Tablet, performance was measured according to Fitts’s Law by using software specially designed for this purpose (MacKenzie, 2018). The detailed measures of performance were the following:

* Words per minute: represents the number of words typed within a minute, the total amount of typed characters was divided by five since a “word” has an average of five characters, measured as words per minute.
* Task duration: refers to the amount of time that takes to the subject to finish the designed task, measured in seconds.
* Throughput: Fitts’s index of performance is calculated over a sequence of trials as a simple quotient. The index of difficulty of the task (in bits) is the numerator and the mean movement time (in seconds) is the denominator, as shown in equation (x):

Eq. (3)

Throughput computed using Eq. 3 is a measure of human performance in the context of the task and device, combining speed and accuracy in performing a target acquisition task (Scott MacKenzie, 2015), measured as bits per second.

***2.3.4 Preference.***

Indicates the tendency of individuals to prefer one condition over another given the presented experimental design. Preference was measured using a two-option survey, interpreted as nominal data. Options were A. Original desk height preferred, or B. Proposal desk height preferred.

***2.3.5. Discomfort.***

To measure the discomfort a 10-point Visual Analog Scale (VAS) was used, where 0 represents no discomfort at all and 10 represents extreme discomfort. Participants were asked to answer the scale for three central regions of the body (Head-Neck, Lower Back, and Hip) and five regions regarding their dominant side (Shoulder-arm, Elbow-forearm, Writs-hand, Thigh-knee, Leg-foot). The resulting data was treated as an ordinal measurement.

**2.4. Procedure.**

Participants attended the Ergonomics and Biomechanics Laboratory of the Faculty of Medicine at Universidad de Valparaíso between April to August 2023 for a 3-hour procedure. Before being assessed, all participants read and completed the informed consent and intake forms.

Prior to staring the test, both the desk and seat were set to match the anthropometric dimensions of each subject with the criteria of each equation. A commercially available adjustable height desk (E-model®) and an adjustable height stool were used for this purpose. Participants then underwent 30 minutes of data collection preparation. This included the evaluation of popliteal height (PH), shoulder height sitting (SHS), and elbow height sitting (EHS) using the principles of ISO 7250-1 (2017). Afterward, the placement of retro-reflective markers and wireless electromyography sensors (described in detail before) and further explanation of trial procedures (figure 1).

Una mujer en frente de una computadora

Descripción generada automáticamente con confianza media

Figure 1. Procedure setup

Prior to data collection, participants completed a calibration trial for the Vicon system, which included the capture of a 3-second window trial for the whole body in a specific position to establish a baseline for markers into the three-dimensional space formed by the Vicon system, and the capture of muscular activity during isometric maximum voluntary contractions (iMVC), as previously described.

To avoid the fatigue and learning effect, the order of desk height was randomized, ensuring that half of the participants started with one of the two conditions, original or proposal. Researchers adjusted the seat height and desk height for the different experimental conditions (independent variable). Participants were instructed to perform the 5 tasks freely but in the same order.

To ensure markers reliability within trials, each participant was asked to begin and end each task in a neutral position designated as the calibration position, which consisted of maintaining a straight back, both arms raised and flexed, hands clasped close to the chest at the level of the xiphoid process, and head looking straight ahead. Subsequently, the participants performed the following tasks freely and in the most comfortable position according to their preference:

1. Handwriting test: The subject transcribed a 250-word text displayed on a notebook onto a sheet of paper using a pen.
2. Reading and attention: The participant read aloud a paragraph of text of no more than 350 words. The positioning of hands and arms during this task was free.
3. Typing test: the participant transcribed a 300-word text into the notebook, using a dedicated typing test (TypingStudy, 2003)
4. Device usage test: The participant performed target acquisition tasks according to Fitts' Law for mobile devices such as Tablets, and computers (using a mouse). Data acquisition and performance variables were measured using GoFitts (Pc) and Fitts Touch (Tablet) software from York University (Scott MacKenzie, 2015).
5. Manipulation of objects: The participant cut a piece of paper with scissors following a predetermined path.

Once all tasks were performed for the first of the two experimental conditions, participants rested for 30 minutes before the repetitions of the tasks for the next condition; before and after each set of tasks, participants were asked to answer a quick survey regarding discomfort. Finally, participants indicate their preference for some of the experimental conditions (workstation configuration). The overall experimental workflow can be seen in Figure 2.

Imagen que contiene Diagrama

Descripción generada automáticamente

Figure 2. Experimental workflow

**2.5. Data Processing**

The processing and analysis of each dependent variable will be presented individually following the five categories mentioned above, kinematics, electromyography, performance, preference, and discomfort.

***2.5.1. Kinematics.***

Shoulder kinematics reconstruction was performed based on the definition of a local joint coordinate system for each rigid body present in our model: Thorax, Head, Arm, and Wrist. Once kinematics was reconstructed for each task separately, markers' trajectory noise was minimized by applying a Woltring filter routine based on mean squared error (Molloy et al., 2008). Since each task started and ended in the same subject’s position (calibration position) event-related processing was necessary to determine the exact moment when each task started and ended.

Target motion-related variables, shoulder flexion and shoulder abduction, were calculated using Vicon Upper Arm model for dynamic trials, where shoulder angles were obtained using Euler angles sequences XZ’Y’’ (intrinsic rotations, where X represents the first rotation, Z the second rotation, and Y is the third rotation).

***2.5.2. Electromyography.***

Following the procedure from kinematics variables, event-related processing was performed for electromyography variables. Data from each of the six muscles was extracted and filtered by implementing a 2nd order low-pass Butterworth filter with a cutoff frequency of 20hz, a frequency previously determined by Fourier analysis of subjects' EMG data (Lindstrom, 1985).

Normalization of muscle activity by using MVIC is a common technique utilized to compare EMG activity between muscles within and between subjects (Halaki and Gi, 2012; Zellers et al., 2019). Next, an iMVC task was asked to be performed by participants prior to the test session to be taken as the reference value for muscle activity for each target muscle. MVIC signal was rectified by calculation of the root mean squared. Then, the maximum value obtained from the processed signal during all three repetitions was used as the reference value for normalizing the EMG signals, resulting in muscle activity from each task to be represented as a percentage of the maximum value (%iMVC).

Following normalized muscle activity calculations, threshold for levels of activity were set based on previous studies (Park, 2013; Zellers et al., 2019). Therefore, mean %iMVC for arm muscles during writing and typing tasks was reported between 10 to 15 %. Thus, low level of muscle activity was set at 5% of iMVC, moderate level at 15%, high level t 25%, and very high levels of activity was any value beyond 25%.

***2.5.3. Performance.***

Performance variables were processed depending on each source of data. For writing, reading, and typing tests, data was obtained from the Vicon system combined with the designated text to be written, read, or typed, taking into consideration the final duration of the task, after the event-related preprocessing, and the number of characters of each text. Data was then averaged for each subject. For the manipulation test, data was obtained also from the Vicon system, but taking only into consideration the time it took for each participant to finish the task at each condition. Finally, performance evaluation in the use of devices were obtained from Fitts Touch and GoFitts test software, using the Fitts index of Performance. The index was calculated as the relationship between the task effective index of difficulty (in bits) computed from the movement amplitude and target width, and the mean of movement time (in seconds), as previously shown in equation 3.

***2.5.4. Preference.***

Preference score given by two options: Original desk height first or Proposal desk height first. The survey was manually processed and exported into a csv file.

***2.5.5. Discomfort.***

Indicates the level of discomfort of each subject, comparing pre (basal) and post levels of discomfort regarding the use of each experimental condition, original and proposal desk height. Discomfort data were normalized by subtracting pre-tasks discomfort ratings from post-tasks discomfort ratings obtained during the same experimental condition (Wiggermann and Keyserling, 2012). Positive values of discomfort against baseline, was interpreted as an increase in discomfort.

**2.6 Statistical analysis**

Following the same structure, all statistical analysis was performed using GraphPad Prism software (version 9.3 for Windows, GraphPad Software, San Diego, California USA, www.graphpad.com). To determine the type of statistical analysis to be used on the performance data, a distribution test was performed for each subset of data using Anderson-Darling, D’Agostino & Pearson, Shapiro-Wilk, and Kolmogorov-Smirnov tests. Distribution for electromyography and kinematics data was determined using a QQ plot.

**2.6.1 Kinematics.**

Kinematics data follows a Gaussian distribution, and to compare the differences between both conditions a paired t-test for total angle of movement for each condition, calculated as the mean of the six tasks for each subject, was performed to determine the effect of the condition regarding the overall shoulder activity. Furthermore, to compare the differences between both conditions regarding kinematics during each task, Two-way ANOVA for repeated measured was performed for shoulder flexion and shoulder abduction variables, where column factor was set as the experimental condition (desk height) and data was entered as means. Multiple comparisons between tasks and the independent variable were also calculated using the Sidak multiple comparisons test.

**2.6.2. Electromyography.**

QQ plot revealed a Gaussian distribution for each subjects’ muscles dataset. It was performed for normalized muscle activity and muscle activity time following the same procedure as for kinematics variables.

**2.6.3. Performance.**

A distribution test was performed, resulting in a Gaussian distribution for each subset of data. To determine the effects of the experimental condition on the performance for each task, a paired t-test with a confidence level of 95% was performed.

**2.6.4. Preference.**

Preference data was sorted by their preference regarding condition (Original and Proposal) and preference (1st or 2nd) was presented into a 2x2 contingency table. A Chi-square test was performed to determine the relation between these two factors.

**2.6.5. Discomfort.**

Discomfort after the execution of tasks was measured against baseline for five regions of the body, Head and Neck, Shoulder and Arm, Elbow and Forearm, Wrist and Hand and Lower Back. Wilcoxon signed-rank test for paired sample was performed to determine the effects of desk height regarding discomfort.

**3. Results.**

**3.1. Kinematics.**

A two-way ANOVA revealed that there was a statistically significant interaction between the effects of desk height and tasks only for shoulder flexion angles . Moreover, simple main effects analysis showed that desk height and task did have a statistically significant effect on both shoulder flexion and shoulder abduction angles (all .

Figure 3 shows the results of Šidák test for multiple comparisons, where there is a significant difference between conditions for Reading, Typing , Device usage for both PC , and Tablet for shoulder flexion, as well as for Typing for Shoulder abduction .

Gráfico, Diagrama

Descripción generada automáticamente

Figure 3. Shoulder Kinematics. Differences between both experimental conditions regarding shoulder flexion angle and shoulder abduction angle for each of the six tasks. Tasks: 1. Writing; 2. Reading; 3. Typing; 4. Device usage (PC); 5. Device usage (Tablet); 6. Object manipulation; 7. Total.

**3.2. Electromyography.**

Results indicate that there was not a statistically significant interaction between the effects of desk height and task for muscle activity on any of the six measured muscles. Figure 4 shows the results of the Šidák test for multiple comparisons, where statistical differences between task and condition were found for: Anterior Deltoids at reading task ; Superior Trapezius at writing and use of electronic device (tablet) tasks. For Medial and Inferior Trapezius , significant differences were found at object manipulation task. For Serratus Anterior, significant differences were found at use of electronic device (tablet) task .

A group of black and white bars

Description automatically generatedFigure 4. Muscle Activity sEMG Normalized against iMVC. Differences between both experimental conditions regarding normalized electromyographical activity presented as % iMVC. Tasks: 1. Writing; 2. Reading; 3. Typing; 4. Device usage (PC); 5. Device usage (Tablet); 6. Object manipulation; 7. Total

In terms of muscle activity and inactivity periods, there is no statistically significant difference between conditions for all tested muscles, as well as no difference regarding task and condition, as shown in Figure 5.

A screenshot of a graph

Description automatically generated

Figure 5. Muscle Activity period. Low and Moderate levels of muscle activity of each target measured muscle during each task measured in seconds. Tasks: 1. Writing; 2. Reading; 3. Typing; 4. Device usage (PC); 5. Device usage (Tablet); 6. Object manipulation; 7. Total

**3.3. Performance.**

Statistical analysis shows that there are no significant differences between the two tested conditions for the different performance-measured variables. Figure 6 shows each variable regarding both desk height conditions.

A black background with white lines

Description automatically generated

Figure 6. Performance. Performance for writing and reading tasks were measured as Words per Minute, whereas Throughput and Time were measured for the use of digital devices and object manipulation tasks respectively.

**3.4. Preference.**

Descriptive analysis shows that 53% of subjects (n:18) preferred the proposed desk height and the other 47% of subjects (n:16) preferred the original desk height. By applying the Chi-square test it was established that there is not dependency between condition (Original and Proposal) and preference (1st or 2nd) (*X*2 = 0.2353, p-value = .6276).

**3.5 Discomfort.**

A total of 22 participants reported discomfort. Of those, 19 reported discomforts in at least one body region after the use of the original desk height, while 17 subjects reported discomfort for the proposal condition. The severity of postural discomfort in the participants while executing the assigned tasks while working with either desk height is presented in table 2. A Wilcoxon signed rank test revealed that there was no significant effect of desk height on change in discomfort (table 2).

Table 2. Discomfort ratings (in points).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Body regions | Discomfort | | | |
| Original Desk Height | Proposal Desk Height | p-value | Summary |
| Head and Neck | 0.147 | 0.147 | .875 | ns |
| Shoulder and Arm | -0.029 | 0.382 | .141 | ns |
| Elbow and Forearm | 0.029 | 0.147 | .500 | ns |
| Wrist and Hand | 0.147 | 0.088 | .688 | ns |
| Lower Back | 0.441 | 0.324 | .738 | ns |

**4. Discussion**

**4.1. Kinematics.**

As expected, the desk height proposal presented greater angles in both flexion and abduction. Although this could in theory present a greater strain on the shoulder joint and muscles, the current study used a desk depth of 80 cm coupled with a "free" posture instructed to the subjects, which allowed them to naturally sit with the forearms fully supported on the desk surface. It was possible to determine that most of the time the participants performed the activities with support from the forearms in both height desk conditions (figure 7). Traditionally, the original equation by Chaffin and Anderson was conceived with the use of typing machines and the initial desktop computer set up, that relied on the assumption of a lower desk height due to subjects using either a typing machine desk or the use of chair armrest for forearm support, which are inherently lower and closer to the traditional elbow height sitting anthropometric dimension (EHS). These results reveal the need for the dimensions of the desk to allow support for the forearms, as corroborated in previous studies (Cabegi de Barros et al., 2022; Santiago et al., 2023) and international regulations , especially with the massification of notebook use over desktop use.

Considering the sample (2,261 students) used in Castellucci et al. (2014) and applying the desk height proposal equation, 94% of the students will use a proper desk height compared with only 63% when applying the original desk height equation based on the Chaffin and Anderson’s principles (Chaffin and Anderson, 1991). Also, the new desk height proposal will allow to use in average a desk higher in 44±6 mm compared with the original desk height. Performing the same calculation, but in a sample of 2,946 workers (Castellucci et al., 2021), it can be established that 46.7% of workers will use a desk higher (high mismatch) than the recommended by the original equation compared to 7.1% of workers using the desk height proposal equation. Also, the new desk height proposal will allow to use on average a desk higher in 52±4 mm compared with the original desk height.

Considering that some authors estimated the higher level of desk height based on the elbow height sitting (EHS) + 50 mm (Dianat et al., 2013; Obinna et al., 2021), the results of the current study can be used to test other data sets. For example, considering the data from previous studies on workers (Castellucci et al., 2021) and schoolchildren (Castellucci et al., 2014), the new proposal will allow to establish new higher level limits for desk height, of EHS + 100mm and EHS + 80 mm for workers and schoolchildren respectively. Other authors are encouraged to try the new proposal in other data sets.

Gráfico, Gráfico de barras

Descripción generada automáticamenteFigure 7. Total time of the tasks performed with support and unsupported forearm.

**4.2. Electromyography.**

Although there was a consistent pattern of higher levels of muscle activity for the Superior Trapezius, the magnitude of changes was only statistical significance for the activities of writing and use of electronic device (tablet) . Even though greater angles were obtained for the new desk height proposal, the results could be related to the amount of supported time of the forearm during these activities (figure 7). Similar results were obtained by Gonçalves et al (2017) who established that forearm support reduced upper trapezius and anterior deltoid activity for all shoulder flexion angles. Furthermore, the use of forearm support compared to the no support condition has been significantly associated with less shoulder muscle activity (Onyebeke et al., 2014). In the current study, there was no notable distinction in muscle activity across the two conditions. As it was shown in Figure 4, %Maximum Voluntary contraction (%MVC) never went beyond 10%, which is far less than the overall criteria of 15% (Kroemer and Grandjean, 1997). This fact implies that below the 15% MVC threshold, theoretically a certain posture can be maintained for extensive periods of time, without experiencing muscle fatigue (Jacquier-Bret and Gorce, 2024; Kroemer and Grandjean, 1997). Therefore, electromyographically, it can be said that the new proposal is as safe for the shoulder as the original criteria stated by Chaffin and Anderson, assuming the forearm is fully supported on the desk's surface.

**4.3. Performance.**

The results obtained reveals that there are no noteworthy distinctions observed between the two conditions tested across various performance-measured variables. Performance measures did not show significant differences between the two desk height conditions, suggesting that performance outcomes were not influenced by desk height variations.

**4.4 Preference*.***

In this study was not possible to establish a difference in the preference between the 2 conditions (Original and Proposal). However, analyzing only the first preference response, it is possible to notice that for the proposal condition (n: 18) 66% of them were women (n:12). However, for the original desk height, most of the preference belongs to men with a 68% preference (n= 11). Chi-Square tests showed a dependency between desk height preference (original first v/s proposal first) and sex (*X*2 = 4.25, p-value = .03925). A possible explanation may be due to the fact that in general, women are more prone to musculoskeletal disorders in the upper limbs and their previous early symptoms, such as pain and discomfort, thus influencing somehow the preference results (Bai et al., 2024) (Yifan Bai et a 2024). The previously cited systematic review states the need to specify gender contribution with its specific characteristics regarding the preference and evaluation of ergonomic design of office furniture. For example, in the current study, gender could have had a role on the dependency of gender and preference, since it has been show that posture varies between man and women (Ohlendorf et al., 2023). Gender specific differences regarding posture could yield preference towards higher or lower desk heights. This hypothesis should be further addressed in specific designs that can account for the role of gender and preferences mediated by specific physical characteristics related to gender specific postures.

**4.5. Discomfort.**

The study findings reveal that there was no primary influence of workstation setup on discomfort. These results could be explained due the small difference between the two-desk heights, where on average the desk height proposal was 48±5 mm higher than the original desk height. Also, the amount of time performing the test could have been not big enough to show differences between the two conditions. The study by Kar and Hedge, (2021) did not show differences in discomfort when comparing two workstation configurations during a test of 60 minutes each.

Other studies presented differences, but the time of intervention ranged from 4 hours (Waongenngarm et al., 2020) to 3 months (Cabegi de Barros et al., 2022). Prolonged seating in experimental settings must be carefully considered to not induce any damage in the subjects. For example, the study of Christensen et al. (2023) shows that with 15 minutes seated computer task caused neck pain in an otherwise healthy population, irrespective of sitting posture. Also the study of Nunes et al. (2021) showed that the significantly risk factors for neck pain were “working without a break for 2 h” [OR: 1.82 (1.00–3.31) P = 0.05] or “more than 3 h”. In general, experimental protocols go through review of the ethics committees, who considering the presented evidence may delay or even reject projects that expose subjects to musculoskeletal pain. Perhaps other field studies could be used in order to test during long period of time in real settings where subjects are already exposed to prolonged seating and assess time exposure related to discomfort reports.

**4.6. Limitations**

To contextualize this study, it is important to acknowledge several limitations. Firstly, the study was conducted in laboratory settings, with each desk height tested for a relatively short 50-minute task duration. This brevity may limit the applicability of findings to educational tasks throughout a full workday. Secondly, while workstation assignments were rotated to mitigate bias, they were completed within a single session separated by a 30-minute rest break. However, despite these constraints, there were no significant differences observed between the workstations.

For future study we recommend the measures of electromyography and posture of the lumbar region, since higher table decreased the lumbar flexion (Mandal, 1994). Similarly, gender differences and their specific postures should be assessed to determine the contributions of gender, posture and preference. Finally, time of the experimental protocols should be further considered, and possibly field testing can be carried out to not expose subject to unnecessary seating time when measuring discomfort.

**5. Conclusion**

In conclusion, our study supports the use of a new equation to define the maximum acceptable elbow rest height considering elbow rest height based on 30° of abduction and 35° flexion. The findings of this research shed light on several important aspects related to desk height adjustment, particularly concerning kinematics, electromyography, performance, preference, and discomfort. Considering the bottom to top matching procedure, when elbow/forearms are fully supported on the desk's surface, all the previously mentioned parameters were kept within safe thresholds. This is highly relevant since one mayor argument for not using the proposed equation could be shoulders with higher flexion and abduction angles (i.e. awkward posture), however while keeping the forearms fully supported the results showed no difference with the original equation. Furthermore, in the current study, most of the test time subjects assumed this position, thus reflecting that forearm/elbow support is a valid and naturally assumed posture when working with a desk in typical and frequently performed tasks, such as typing, reading or performing light manual tasks.

In summary, while the proposed desk height adjustment showed promising results further research is warranted to explore its long-term effects considering gender-specific preferences and posture variations. Additionally, future studies should consider incorporating lumbar posture assessments and longer intervention durations to provide more comprehensive insights into the impact of desk height adjustments on overall workstation ergonomics.

**6. References**

Altaboli, A., Aliskandarani, H., Alshaikhi, A., Alahmar, H., Muttardi, R., 2023. Anthropometric Evaluation of University Classroom Furniture, in: Physical Ergonomics and Human Factors. https://doi.org/10.54941/ahfe1003040

Bai, Y., Kamarudin, K.M., Alli, H., 2024. A systematic review of research on sitting and working furniture ergonomic from 2012 to 2022: Analysis of assessment approaches. Heliyon 10, e28384. https://doi.org/10.1016/j.heliyon.2024.e28384

Cabegi de Barros, F., Moriguchi, C.S., de Oliveira Sato, T., 2022. Effects of workstation adjustment to reduce postural exposure and perceived discomfort among office workers - A cluster randomized controlled trial. Appl. Ergon. 102, 103738. https://doi.org/10.1016/j.apergo.2022.103738

Cantin, N., Delisle, I., Baillargeon, M., 2019. Reducing Child-Furniture Incompatibility in Primary Schools. J. Occup. Ther. Sch. Early Interv. 12, 200–209. https://doi.org/10.1080/19411243.2018.1538843

Carneiro, V., Gomes, A., Rangel, B., 2017. Proposal for a universal measurement system for school chairs and desks for children from 6 to 10 years old. Appl. Ergon. 58, 372–385. https://doi.org/10.1016/j.apergo.2016.06.020

Castellucci, H.I., Arezes, P.M., Molenbroek, J.F.M., 2015. Equations for defining the mismatch between students and school furniture: A systematic review. Int. J. Ind. Ergon. 48, 117–126. https://doi.org/10.1016/j.ergon.2015.05.002

Castellucci, H.I., Arezes, P.M., Molenbroek, J.F.M., 2014. Applying different equations to evaluate the level of mismatch between students and school furniture. Appl. Ergon. 45, 1123–32. https://doi.org/10.1016/j.apergo.2014.01.012

Castellucci, H.I., Arezes, P.M., Molenbroek, J.F.M., de Bruin, R., Viviani, C., 2017. The influence of school furniture on students’ performance and physical responses: results of a systematic review. Ergonomics 60, 93–110. https://doi.org/10.1080/00140139.2016.1170889

Castellucci, H.I., Viviani, C., Arezes, P., Molenbroek, J.F.M., Martínez, M., Aparici, V., 2021. Application of mismatch equations in dynamic seating designs. Appl. Ergon. 90, 103273. https://doi.org/10.1016/j.apergo.2020.103273

Chaffin, D., Anderson, G., 1991. Occupational Biomechanics, 2nd ed. John Wiley, New York.

Christensen, S.W.M.P., Palsson, T.S., Krebs, H.J., Graven-Nielsen, T., Hirata, R.P., 2023. Prolonged slumped sitting causes neck pain and increased axioscapular muscle activity during a computer task in healthy participants – A randomized crossover study. Appl. Ergon. 110. https://doi.org/10.1016/j.apergo.2023.104020

de Bruin, R., Castellucci, H.I., 2022. School Furniture and Anthropometric Fit, the Gap Between Theory and Practice. Ergon. Des. Q. Hum. Factors Appl. 106480462110672. https://doi.org/10.1177/10648046211067290

Dianat, I., Javadivala, Z., Asghari-Jafarabadi, M., Asl Hashemi, A., Haslegrave, C.M., 2013. The use of schoolbags and musculoskeletal symptoms among primary school children: are the recommended weight limits adequate? Ergonomics 56, 79–89. https://doi.org/10.1080/00140139.2012.729612

Gligorović, B., Desnica, E., Palinkaš, I., 2018. The importance of ergonomics in schools - Secondary technical school students’ opinion on the comfort of furniture in the classroom for computer aided design. IOP Conf. Ser. Mater. Sci. Eng. 393. https://doi.org/10.1088/1757-899X/393/1/012111

Gómez Echeverry, L.L., Jaramillo Henao, A.M., Ruiz Molina, M.A., Velásquez Restrepo, S.M., Páramo Velásquez, C.A., Silva Bolívar, G.J., 2018. Human motion capture and analysis systems: a systematic review/Sistemas de captura y análisis de movimiento cinemático humano: una revisión sistemática. Prospectiva 16, 24–34. https://doi.org/10.15665/rp.v16i2.1587

Gonçalves, J.S., Shinohara Moriguchi, C., Takekawa, K.S., Coury, H.J.C.G., Sato, T. de O., 2017. The effects of forearm support and shoulder posture on upper trapezius and anterior deltoid activity. J. Phys. Ther. Sci. 29, 793–798. https://doi.org/10.1589/jpts.29.793

Halaki, M., Gi, K., 2012. Normalization of EMG Signals: To Normalize or Not to Normalize and What to Normalize to?, in: Computational Intelligence in Electromyography Analysis - A Perspective on Current Applications and Future Challenges. InTech. https://doi.org/10.5772/49957

ISO, 2017. ISO 7250-1: Basic human body measurements for technological design - Part 1: Body measurement definitions and landmarks. International Organization for Standardization, Geneva, Switzerland.

Jacquier-Bret, J., Gorce, P., 2024. Global Upper Body Assessment (GUBA) - A new Tool to Identify the Indicators That will lead to the Occurrence of Musculoskeletal Disorders of Light Weight Loads in Seated Position Based Body Mass Index and Postural Strategy. Int. J. Heal. Sci. Res. 14, 257–272. https://doi.org/10.52403/ijhsr.20240338

Kahya, E., 2019. Mismatch between classroom furniture and anthropometric measures of university students. Int. J. Ind. Ergon. 74, 102864. https://doi.org/10.1016/j.ergon.2019.102864

Kar, G., Hedge, A., 2021. Effect of workstation configuration on musculoskeletal discomfort, productivity, postural risks, and perceived fatigue in a sit-stand-walk intervention for computer-based work. Appl. Ergon. 90. https://doi.org/10.1016/j.apergo.2020.103211

Kett, A.R., Sichting, F., 2020. Sedentary behaviour at work increases muscle stiffness of the back: Why roller massage has potential as an active break intervention. Appl. Ergon. 82, 102947. https://doi.org/10.1016/j.apergo.2019.102947

Khoshabi, P., Nejati, E., Ahmadi, S.F., Chegini, A., Makui, A., Ghousi, R., 2020. Developing a multi-criteria decision making approach to compare types of classroom furniture considering mismatches for anthropometric measures of university students. PLoS One 15, 1–25. https://doi.org/10.1371/journal.pone.0239297

Kroemer, K.H.E., Grandjean, E., 1997. Fitting the task to the human. A textbook of occupational Ergonomics.

Lee, S., De Barros, F.C., De Castro, C.S.M., De Oliveira Sato, T., 2021. Effect of an ergonomic intervention involving workstation adjustments on musculoskeletal pain in office workers—a randomized controlled clinical trial. Ind. Health 59, 78–85. https://doi.org/10.2486/indhealth.2020-0188

Lee, Y., Yun, M.H., 2019. Evaluation of the guidelines and children’s ability to select the anthropometrically recommendable height of school furniture: A case study of Korean primary school children. Work 64, 427–438. https://doi.org/10.3233/WOR-193005

Lindstrom, L., 1985. Spectral analysis of EMG., in: Lectromyography and Evoked Potentials. Theories and Applications. Springer-Verlag, New York., pp. 103–107.

Macedo, A.C., Morais, A. V, Martins, H.F., Martins, J.C., Pais, S.M., Mayan, O.S., 2015. Match between classroom dimensions and students’ anthropometry: re-equipment according to European educational furniture standard. Hum. Factors 57, 48–60. https://doi.org/10.1177/0018720814533991

MacKenzie, I.S., 2018. Fitts’ Law, in: The Wiley Handbook of Human Computer Interaction. Wiley, pp. 347–370. https://doi.org/10.1002/9781118976005.ch17

Mandal, A., 1994. Influence of furniture height on posture and back pain, in: Lueder, R., Noro, K. (Eds.), Hard Facts about Soft Machines: The Ergonomics of Seating. Taylor & Francis, London, pp. 173–178.

Marras, W.S., 2012. Basic Biomechanics and Workstation Design, in: Handbook of Human Factors and Ergonomics. Wiley, pp. 347–381. https://doi.org/10.1002/9781118131350.ch12

Molloy, M., Salazar-Torres, J., Kerr, C., McDowell, B.C., Cosgrove, A.P., 2008. The effects of industry standard averaging and filtering techniques in kinematic gait analysis. Gait Posture 28, 559–562. https://doi.org/10.1016/j.gaitpost.2008.03.012

Nunes, A., Espanha, M., Teles, J., Petersen, K., Arendt-Nielsen, L., Carnide, F., 2021. Neck pain prevalence and associated occupational factors in Portuguese office workers. Int. J. Ind. Ergon. 85, 103172. https://doi.org/10.1016/j.ergon.2021.103172

Obinna, F.P., Sunday, A.A., Babatunde, O., 2021. Ergonomic assessment and health implications of classroom furniture designs in secondary schools: a case study. Theor. Issues Ergon. Sci. 22, 1–14. https://doi.org/10.1080/1463922X.2020.1753259

Ohlendorf, D., Avaniadi, I., Adjami, F., Christian, W., Doerry, C., Fay, V., Fisch, V., Gerez, A., Goecke, J., Kaya, U., Keller, J., Krüger, D., Pflaum, J., Porsch, L., Loewe, C., Scharnweber, B., Sosnov, P., Wanke, E.M., Oremek, G., Ackermann, H., Holzgreve, F., Keil, F., Groneberg, D.A., Maurer-Grubinger, C., 2023. Standard values of the upper body posture in healthy adults with special regard to age, sex and BMI. Sci. Rep. 13, 1–16. https://doi.org/10.1038/s41598-023-27976-8

Onyebeke, L.C., Young, J.G., Trudeau, M.B., Dennerlein, J.T., 2014. Effects of forearm and palm supports on the upper extremity during computer mouse use. Appl. Ergon. 45, 564–570. https://doi.org/10.1016/j.apergo.2013.07.016

Parcells, C., Stommel, M., Hubbard, R.P., 1999. Mismatch of classroom furniture and student body dimensions: empirical findings and health implications. J. Adolesc. Heal. 24, 265–273.

Park, S., 2013. Comparison of Muscle Activation during Dominant Hand Wrist Flexion when Writing. J. Phys. Ther. Sci. 25, 1529–1531. https://doi.org/10.1589/jpts.25.1529

Parvez, M.S., Rahman, A., Tasnim, N., 2019. Ergonomic mismatch between students anthropometry and university classroom furniture. Theor. Issues Ergon. Sci. 20, 603–631. https://doi.org/10.1080/1463922X.2019.1617909

Pheasant, S., 2003. Bodyspace, Second. ed. Taylor & Francis, London.

Santiago, R.J., Santos Baptista, J., Magalhães, A., Torres Costa, J., 2023. Total forearm support during a typing task may reduce the risk of Trapezius’ Myalgia development. Int. J. Ind. Ergon. 95. https://doi.org/10.1016/j.ergon.2023.103449

Scott MacKenzie, I., 2015. Fitts’ Throughput and the Remarkable Case of Touch-Based Target Selection, in: Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). pp. 238–249. https://doi.org/10.1007/978-3-319-20916-6\_23

Slot, T., Charpentier, K., 2009. Evaluation of forearm support provided by the Workplace Board on perceived tension , comfort and productivity in pregnant and non-pregnant computer users. Work A J. Prev. Assess. Rehabil. 34, 67–77. https://doi.org/10.3233/WOR-2009-0903

van Niekerk, S.-M., Louw, Q.A., Grimmer-Somers, K., Harvey, J., Hendry, K.J., 2013. The anthropometric match between high school learners of the Cape Metropole area, Western Cape, South Africa and their computer workstation at school. Appl. Ergon. 44, 366–71. https://doi.org/10.1016/j.apergo.2012.09.008

Vio del Rio, F., 2018. Aumento de la obesidad en chile y en el mundo. Rev. Chil. Nutr. 45, 6–6. https://doi.org/10.4067/S0717-75182018000100006

Waongenngarm, P., van der Beek, A.J., Akkarakittichoke, N., Janwantanakul, P., 2020. Perceived musculoskeletal discomfort and its association with postural shifts during 4-h prolonged sitting in office workers. Appl. Ergon. 89, 103225. https://doi.org/10.1016/j.apergo.2020.103225

Wiggermann, N., Keyserling, W.M., 2012. Effects of Anti-Fatigue Mats on Perceived Discomfort and Weight-Shifting During Prolonged Standing. Hum. Factors J. Hum. Factors Ergon. Soc. 55, 764–775. https://doi.org/10.1177/0018720812466672

Yanto, Lu, C.W., Lu, J.M., 2017. Evaluation of the Indonesian National Standard for elementary school furniture based on children’s anthropometry. Appl. Ergon. 62, 168–181. https://doi.org/10.1016/j.apergo.2017.03.004

Zellers, J.A., Parker, S., Marmon, A., Grävare Silbernagel, K., 2019. Muscle activation during maximum voluntary contraction and m-wave related in healthy but not in injured conditions: Implications when normalizing electromyography. Clin. Biomech. 69, 104–108. https://doi.org/10.1016/j.clinbiomech.2019.07.007