Impact of digital boards on hand and neck muscle activity during online teaching process

S. Shankar1 · R. Naveenkumar2 · R. Nithyaprakash1 · S. Narmatha1 · R. Rithic Sai1 · M. Nandhakumar1

Abtract
Academicians across the globe due to Covid 19 shifted to online teaching as a mainstream method by replacing the chalk and talk method. The main objective of this study is to find the impact of different sizes of digital boards used for online teaching on muscle activity and muscle fatigue, and then results are compared with conventional writing. Initially, a questionnaire survey is conducted among 100 college professors about the issue they faced while using online teaching methods. Experimental analysis are then conducted using electromyography sensor (sEMG) among ten college professors and their muscle activity on the dominant hand and neck while writing on two commercially available digital boards namely Type 1 (small writing area) and Type 2 (large writing area). Four muscles namely Flexor carpi radialis, Extensor carpi radialis, Biceps brachii, and Sternocleidomastoid (SCM) are chosen for the study. The results are then compared with muscle activity while writing on conventional A4 sheets. Normalized root mean square (RMS) is used to assess the muscle activity and the trend line of MPF value is utilized to assess the muscle fatigue. The results show that SCM muscle has more muscle activation compared to other selected muscles followed by flexor carpi radialis. Subjective analysis is carried out using the Borg scale, which has reported that Type 2 digital board having larger working area was preferred by the participants as it reduces muscle fatigue.

Keywords Digital board · Muscle activity · sEMG · Borg scale · RMS · Online teaching

S. Shankar
shankariitm@gmail.com

1 Department of Mechatronics Engineering, Kongu Engineering College, Erode, Tamil Nadu 638060, India

2 Department of Mechanical Engineering, Kongu Engineering College, Erode, Tamil Nadu 638060, India
1 Introduction

The development of miniature computing devices and technologies has helped the teaching community to use digital teaching tools to handle this pandemic outbreak due to COVID 19 (Berger et al., 2021). The partial and complete shutdown of schools and universities due to COVID 19 has forced teachers to adopt the online mode of teaching (Cutri & Mena, 2020). Online teaching increases the meaningful learning that contributes positively to the students for academic learning and increases motivation (Chau et al., 2020, Biçak, 2019, Yalman & Basaran, 2021). The sudden transition to online mode without proper training and minimum interaction with students has made online teaching more challenging and stressful for teachers (König et al., 2020). Usage of digital tools without proper training in a distressed environment for a prolonged time at static posture can result with several Musculoskeletal Disorder (MSD) (Tittiranonda et al., 1999; Zoltan et al., 2019). Psychological factors and depression are the major factors having a significant correlation with the occurrence of MSD among teachers (Ng et al., 2019; Titheradge et al., 2019). Shoulder, neck, foot, upper back and lower back are the highly affected regions among the teachers due to various job-related risk factors like awkward postures, working hours, and types of shoes used (Alias et al., 2020; Damayanti et al., 2017; Ojukwu et al., 2018). The height of the writing board has an impact on the neck and shoulder muscles namely Sternocleidomastoid (SCM), Trapezius, and Deltoid among the teachers, resulting in muscle fatigue and trauma (Ojukwu et al., 2020; Petronilla et al., 2020; Shankar et al., 2021). The awkward posture adopted by teachers such as neck forward posture, elevated arm postures results in MSD (Kataria et al., 2020; Shankar et al., 2021).

Past research has reported that the neck, shoulder, and back are highly affected anatomical regions due to the prolonged usage of smart computing devices like computers, phones, and tablets (Choi, 2018; Erick & Smith, 2011). Work posture, psychological condition, and demographical characteristics have a significant correlation with the occurrence of MSD among computer users (Namwongsa et al., 2018; Sasikumar, 2018). Keyboard design, typing speed, and work posture in digital tools influence the muscle activation of the neck, hand, and shoulder (Kang et al., 2019; Lin et al., 2020). Muscle activation on the neck and shoulder increases while using a larger size keyboards compared to a smaller size keyboards (Besharati et al., 2020; Van Beek et al., 2019). Working posture and position of mobiles, tablets, computers can influence muscle activity (Areuedomwong et al., 2018; Bodin et al., 2019; Douglas & Gallagher, 2017; Park et al., 2017).

From the literature, it was found that many research studies were carried out in past to identify the effect of various risk factors like working postures, cognitive load, design, and position of instruments on the occurrence of MSD among teachers and digital devices users. Still, no research work was carried out to address the effect of writing task using the digital boards.
on muscle activation among the teaching professionals. This study aims to find the impact of different size digital boards on the hand and neck muscle engagement during the writing process by comparing the results with the conventional writing methods and to recommend the optimum digital board size for teaching purpose.

2 Materials and methods

2.1 Pilot study-questionnaire survey

An online questionnaire survey was conducted as a pilot study to find the effect of WMSD on different anatomical regions while handling online classes among the college professors from eight academic Institutes in Tamil Nadu, India. The questionnaire was prepared based on the modified Nordic Questionnaire using Google form and sent to 120 college professors through E-mail. Participants were selected randomly from the database available on their college websites. Participants with history of bone dislocation and chronic muscular illness were excluded from the study. Also, participants within minimum six months of experience in online teaching and one year in conventional teaching were chosen as a selection criterion to participate in this pilot study.

The survey consists of three sections for collecting information related to demographical, Psychological, and job-related questions to evaluate the frequency and intensity of WMSD. The questions were of closed type with yes or no option, for example ‘Do you experience neck pain at the end of online teaching’. In total, we received 100 responses comprising both male and female professors. The study population has 56 male and 44 female professors with a mean age of 37.18 ± 6.86 years (Mean ± SD), teaching experiences 12.49 ± 6.7 (Mean ± SD) years, experiences in digital board use 10.9 ± 5.33 (Mean ± SD) months, height 168.9 ± 39.93 (Mean ± SD) cm, weight 69.59 ± 13.87 (Mean ± SD) kg. Collected data were analysed using the statistical software package SPSS V21.0. Descriptive analysis was done on the collected data to find the prevalence of WMSD on various anatomical regions.

2.2 Study participants for experimental studies

Ten male professors from the Kongu Engineering College, Perundurai, Erode were volunteered to participate in this experimental study. All the participants were having prior experience of using the digital board for more than six months. Participants were having a mean age of 30.7 years, mean height of 173 cm, weight 74.9 cm, teaching experience of 5.8 years, and mean digital board usage experience of 3.3 months. All the participants were well explained about the scope of the study before starting of experimental trials and written consent were
obtained from them. The study was approved by the ethics committee of Kongu institutions. Subjective discomfort ratings were also carried out using Borg’s Rating of Perceived Exertion (RPE) scale. The participants were asked to rate the muscle discomforts and preference digital boards on the 6–20 rating scale at the end of each experimental trial.

2.3 Experimental protocol

Experimental analysis was carried out by recording the muscle activity on hand and neck muscles while using two different size digital boards namely Type 1 digital board with a small working area (Make: Star G640; Writing area: 190.5 × 161.5 mm) and Type 2 digital board with the larger working area(Make: Star03; Writing area: 362 × 210 mm). The muscle engagement while using Type 1 and Type 2 digital boards was compared with writing on an A4 sheet. The same size pen (Make; XP; Diameter: 38 mm) was used for writing in both digital boards, whereas for writing in A4 sheet ballpoint pen (Make: Reynolds; Model: brite; diameter: 24 mm) was used. During the study, participants were asked to sit on the classroom table having the height of 40 cm sitting table and writing table of height 72 cm with writing surface inclining 15 degrees. The participants were requested to write the given paragraph (about 400 words and draw geometric shapes like circles, rectangles within 2 min). During the writing session, participants were requested to sit straight with thighs parallel to the floor and keep their feet firmly on the ground (Lin et al., 2020).

2.4 Task performed

The participants were asked to write the given two paragraphs (about 400 words) and draw geometric shapes using Type 1, Type 2 digital boards, and A4 sheet within 2 min as shown in Fig. 1(a–c). Ten minutes of rest were provided between every trial to avoid the error due to muscle fatigue. Participants were also told to maintain the same writing pace during the experiment to reduce muscle exhaustion from the previous trial. Before the start of the experiment, the participants were trained for writing on the different size digital boards to avoid any error during the experiments.

2.5 Muscle’s selection

The four muscles’ from the dominant hand and neck were selected for this experiment study based on the results from the online questionnaire survey conducted prior to experimental study and literature survey. The muscles chosen for the experiment were namely Biceps brachii right, Flexor carpi radialis right, Extensor carpi radialis right, and SCM right. The maximum voluntary isometric contraction (MVIC) for selected muscle was obtained by asking the participants to perform the following activity for 5 s with 2 min break between each trial (Merino et al., 2019).
For finding out the MVIC value for the SCM muscle, participants were asked to perform cervical flexion and contraction (Shankar et al., 2019). For biceps brachii, the participants were asked to do push-ups on the floor. For flexor carpi radialis, the participants were asked to do wrist flexion with the forearm supinated by leaning on the table and elbow is flexed to 120°. Whereas for extensor carpi radialis, the participants were asked to do wrist extension with pronated by leaning on the table and elbow was flexed to 120° (Rota et al., 2013).

2.6 Electrode placement

Surface electromyography (sEMG) sensors were placed on the bellies of Flexor Carpi Radialis muscle, Extensor Carpi Radialis muscle, Biceps Brachii muscle, and SCM muscle as shown in Fig. 2. The electrode was positioned on the muscles
bellies based on a literature study as mentioned in Table 1 (Ahamed et al., 2012; Almosnino et al., 2009; Ghapanchizadeh et al., 2015). Die-cut double-sided sticker was used to place the gel-free sEMG sensors on the muscle bellies. Before placing the electrodes, the specific muscle region was cleaned using a dry cloth to avoid the sticker peeling due to sweat. Minimum skin preparation was enough to stick the sensors on bellies of the muscles since the sEMG electrodes used for this study were having high input impedance. The sEMG sensors were calibrated to zero while the participants maintained a calm stance with no muscle groups involved.
2.7 Instruments and measurement

An eight-channel data LOGEMG system (Biometrics, UK) with a 20 kHz sampling rate per channel was used to record muscle activity during the experimental trial. To record the selected muscle movement, four surface sEMG sensors (SX230-1000, Biometrics, UK) were interfaced with data LOG. Data LOG was connected to a Laptop and raw sEMG data was stored in it. The raw sEMG signals were captured at a sample rate of 1,000 samples per second, and the input impedance of the sEMG sensors was greater than 100 Mega ohms.

Raw sEMG data was filtered using Butterworth fourth-order filter in the range of 20- 400 Hz and rectified using MATLAB R2016a, (Lin et al., 2020). The MPF value was calculated separately to find the muscle fatigue concerning time to find out the presence of muscle fatigue (Balasubramanian & Jayaraman, 2009; Subramanian et al., 2018). RMS value from the filtered and rectified data was calculated and normalized with MVIC data to compute the muscle activity during continuous isometric contraction (Huang & Ai, 2017). One way ANOVA and Pair-wise comparison test was conducted using the post hoc test with Turkey’s adjustment in SPSS 21.

3 Results

A pilot study conducted through an online questionnaire survey has reported that hand; neck and shoulder were the anatomical regions experiencing pain while using the digital board in online classes. Figure 3 shows result of online questionnaire survey, It reported that neck (n = 55) was the highly affected body region during online classes, followed by shoulder (n = 53) and hand (n = 39). Also, 58%
of the study population has preferred the conventional teaching methods over online teaching and also 39% (n = 39) of study populations were experiencing high to a very high level of job-related stress during online teaching season. An experimental analysis was carried out using sEMG sensors to study the muscle activation on hand and neck muscle while using the digital board with different working area and then the results were compared with muscle engagement during conventional writing on an A4 sheet. Totally 10 professors participated in this experimental study and the muscle activation during the study was shown in Fig. 4. It was inferred from Fig. 4 that the activation of the muscles was not uniform in all three methods of writing. Biceps brachii shows less muscle activation than the other three muscles chosen for the study during the writing process. Also, Extensor carpi radialis doesn’t have much variation in muscle engagement while writing on two different sizes digital boards and A4 sheet. The results indicated that the writing area and size of the pen used did not impact the muscle activity of biceps brachii and extensor carpi radialis. Unlike these two muscles, Flexor carpi radialis and SCM were influenced by the working area of the digital boards and pen used, since they exhibit elevated muscle activity. Type 1 digital board requires a higher level of flexor carpi radialis muscle activation for smooth writing when compared with writing on Type 2 and A4 sheets. SCM (neck) muscle activation was more or less equal in the Type 2 digital board and A4 sheet.
MPF value was calculated for every 30 s and a graph was plotted against the time to find the linearity since the rate of linearity of the MPF plot was used to find the presence of muscle fatigue (Subramaniam et al., 2018; Washino et al., 2017). Figure 5 shows the MPF plot of flexor carpi radialis muscle (highly active in all three modes of writing) while writing on Type 1, Type 2 digital boards, and A4 sheet. It was found that the linearity of the MPF plot was higher in Type 1 digital board compared to the other two methods of writing indicating that the muscles were getting more fatigue while using the Type 1 digital board.

Table 2 provided that the result of statistical analysis which was performed to determine the relationship between the activity in the muscle groups and different

| Muscles               | F values | P values |
|-----------------------|----------|----------|
| Flexor carpi radialis | 0.529    | 0.596    |
| Extensor carpi radialis | 0.036  | 0.964    |
| Biceps brachii        | 0.519    | 0.601    |
| SCM                   | 0.051    | 0.951    |

Fig. 5 a-c MPF plot of Flexor Carpi Radialis muscle
writing instruments. The post hoc test with the Turkey approach was also used to do a pair-wise comparison test, which revealed that there is no significant variation between the writing instruments used. Table 3 shows the result of subjective analysis carried out to determine the mean discomfort rating of muscle. Most participants (7 of 10) preferred writing on an A4 sheet followed by Type 2 digital board and Type 1 as most discomfort devices to use. Also rated Flexor carpi radialis and SCM muscle was causing discomfort during the experimental trial.

4 Discussion

In this study, the effect of working space in digital boards on the neck and hand muscles activity during writing was analysed and the compared with normal writing on an A4 sheet. The muscle activity and fatigue characteristics were evaluated using the Electromyography sensor (sEMG) (Greco et al., 2019; Hof, 1984; Wu & Luo, 2006). Figure 4 indicated that there was a difference in muscle activation on the hand and neck muscles while writing on a digital board and A4 sheet. Figure 4 also inferred that Type 2 digital board and A4 sheet require the higher activity of SCM muscle activation while writing when compared with Type 1 digital boards. Type 2 digital boards had a slightly higher level of SCM muscle activation compared to the A4 sheet; this may be because of the large writing space that demands more holding time of the pen and forwarded neck posture for seeing the monitor of the computer. Flexor carpi radialis muscle activation was higher while writing on Type 1 digital board compared to other two methods, small working space since the higher frequency of hand movements and altering the position of the hand might be the reason for the above. The increased angle between the hand elbow joints may be the reason for the elevated muscle activation of biceps brachii in Type 2 digital board compared to the other two methods of writing (Gao et al., 2020).

The Mean Power Frequency (MPF) values for each four muscle groups were calculated from the raw sEMG file during continuous writing activity for 2 min. Figure 5 shows the MPF plot of flexor carpi radialis muscle which was linearly decreasing, concerning time indicating the presence of muscle fatigue. Comparing the devices, it was inferred from Fig. 5 that Type 1 digital board exhibits a higher level of muscle fatigue for all selected muscles expect SCM muscle may

| Muscle                  | Type 1 digital board | Type 2 digital board | A4 Sheet | Average Borg’s RPE scale rating |
|-------------------------|----------------------|----------------------|----------|--------------------------------|
| Flexor carpi radialis   | 11                   | 8.8                  | 10.8     | 10.2                           |
| Extensor carpi radialis | 8.2                  | 9.0                  | 8.2      | 8.4                            |
| Biceps brachii          | 8.2                  | 8.6                  | 8.0      | 8.2                            |
| SCM                     | 9.8                  | 11                   | 12       | 10.9                           |
be due to the higher frequency of hand movement due to small writing space compared to the other two methods. Type 2 digital board exhibits higher muscle fatigue for SCM muscle that correlates well with other muscle activity. A high rate of muscle fatigue on flexor carpi radialis may be due to the diameter of the pen used for writing since which was bigger than conventional pens (Wu & Luo, 2006).

Results of the ANOVA test shown in Table 2 infers that there was no statistical significance found between the different sizes of the digital board and muscle activation, this may be due to the low values of normalized MVIC values (Shimomura et al., 2016). But muscle activation and muscle fatigue results indicating the difference in digital board size and writing area has an impact on muscle activation. The subjective analysis carried out using the Borg RPE scale has also supported the above statement. In subjective analysis, the participants rated that the SCM muscle as most discomfort and preferred conventional method of writing on A4 sheet compared to digital boards. Among digital boards, Type 2 was preferred by the study population. Maintaining neck forward position while using digital board, the larger diameter of pen used and repeated head movement may be the reason for the discomfort rating. The limitation in the present study was that we have chosen only four muscles because of practical limitations, and if we had chosen shoulder muscle activity and biomechanical joint angles more insight into the muscle activation may be obtained. Also we didn’t consider the cognitive load and its impact on the reported WMSD. The visual strain on eyes due to continuous exposure to computer screens and comparison on productivity concerning writing speed can be considered for future studies.

5 Conclusion

Use of digital boards as a teaching aid in online cause musculoskeletal distress among the teaching community. In this work, questionnaire survey was conducted prior to experimental analysis to find the prevalence of WMSD among teaching profession. Questionnaire survey results revealed that neck and shoulder were affected due to WMSD during online teaching. Then experimental study was performed using sEMG sensors to find the impact of digital boards with variable working area on muscle activation patterns in the hand and neck region. The experimental result shows that digital board with small working area exhibit high muscle activity compared to larger working area. Neck (SCM) and Hand muscles (flexor carpi radialis) were engaged more during the study. Apart from the digital board writing area, other factors like neck forward posture and repeated hand movements were influencing the muscle activity during the writing process. This study recommends the digital board with a larger writing surface for teaching to prevent the musculoskeletal distress. Study population also rated digital board with larger working space as most comfortable. These experimental results gave the deeper insight on the impact
of working space in digital board on muscle activity and can be utilized for future research.

**Declarations**

**Conflict of interest** The authors declare that they don’t have any potential conflict of interest in this work.

**References**

Ahamed, N. U., Sundaraj, K., Ahmad, R. B., Rahman, M., Islam, A., & Ali, A. (2012). Analysis of the effect on electrode placement on an adolescent’s biceps brachii during muscle contractions using a wireless EMG sensor. *Journal of Physical Therapy Science*, 24, 609–611.

Alias, A. N., Karupiah, K., How, V., & Perumal, V. (2020). Prevalence of musculoskeletal disorders (MSDS) among primary school female teachers in Terengganu, Malaysia. *International Journal of Industrial Ergonomics*, 77, 102957.

Almosnino, S., Pelland, L., Pedlow, S. V., & Stevenson, J. M. (2009). Between-day reliability of electromechanical delay of selected neck muscles during performance of maximal isometric efforts. *BMC Sports Science, Medicine and Rehabilitation*, 1, 1–8.

Areeudomwong, P., Oapdunsalam, K., Havicha, Y., Tantai, S., & Buttagat, V. (2018). Effects of shoulder taping on discomfort and electromyographic responses of the neck while texting on a touchscreen smartphone. *Safety and Health at Work*, 9, 319–325.

Balasubramanian, V., & Jayaraman, S. (2009). Surface EMG based muscle activity analysis for aerobic cyclist. *Journal of Bodywork and Movement Therapies*, 13, 34–42.

Berger, R., Mallow, A., Tabag, K., White, C. T., Fiore, C., Schachar, A., & Hirsch, E. 2021. Teaching and learning in a time of corona: A social work experience. *Clinical Social Work Journal*, 1–12.

Besharati, A., Daneshmandi, H., Zareh, K., Fakherpour, A., & Zoaktafi, M. (2020). Work-related musculoskeletal problems and associated factors among office workers. *International Journal of Occupational Safety and Ergonomics*, 26, 632–638.

Biçak, F. (2019). Investigation of the views of teachers toward the use of smart boards in the teaching and learning process. *Journal of Pedagogical Research*, 3, 15–23.

Bodin, T., Berglund, K., & Forsman, M. (2019). Activity in neck-shoulder and lower arm muscles during computer and smartphone work. *International Journal of Industrial Ergonomics*, 74, 102870.

Chau, K. T., Zainuddin, D. A. B., Ling, S. K., Ng, L. M., & Yang, J. (2020). The perception of teachers towards smart Board Technology in a Malaysian Primary School. *International Journal of Information and Education Technology*, 10, 405–409.

Choi, H.-S. (2018). EMG sensor system for neck fatigue assessment using RF wireless power transmission. 2018 3rd International Conference on Computational Intelligence and Applications (ICCIA). IEEE, pp. 219–222.

Cutri, R. M., & Mena, J. (2020). A critical reconceptualization of faculty readiness for online teaching. *Distance Education*, 41, 361–380.

Damayanti, S., Zorem, M., & Pankaj, B. (2017). Occurrence of Work Related Musculoskeletal Disorders among School Teachers in Eastern and Northeastern Part of India. *International Journal of Musculoskeletal Pain Prevention*, 2, 187–192.

Douglas, E. C., & Gallagher, K. M. (2017). The influence of a semi-reclined seated posture on head and neck kinematics and muscle activity while reading a tablet computer. *Applied Ergonomics*, 60, 342–347.

Erick, P. N., & Smith, D. R. (2011). A systematic review of musculoskeletal disorders among school teachers. *BMC Musculoskeletal Disorders*, 12, 1–11.

Gao, J., Han, C., Huang, W., Gao, J., & Nie, L. (2020). Experimental study on the sEMG of "joint angle effect" of human muscle strength—Taking biceps brachii as an example. E3S Web of Conferences. EDP Sciences, 01021.
Ghapanchizadeh, H., Ahmad, S. A., & Ishak, A. J. (2015) Recommended surface EMG electrode position for wrist extension and flexion. 2015 IEEE Student Symposium in Biomedical Engineering & Sciences (ISSBES). IEEE, pp. 108–112.

Greco, A., Valenza, G., Bicchi, A., Bianchi, M., & Scilingo, E. P. (2019). Assessment of muscle fatigue during isometric contraction using autonomic nervous system correlates. Biomedical Signal Processing and Control, 51, 42–49.

Hof, A. L. (1984). EMG and muscle force: An introduction. Human Movement Science, 3, 119–153.

Huang, X., & Ai, Q. (2017). A Comparison of Assessment Methods for Muscle Fatigue in Muscle Fatigue Contraction. Springer.

Kang, B.-R., Her, J.-G., Lee, J.-S., Ko, T.-S., & You, Y.-Y. (2019). Effects of the computer desk level on the musculoskeletal discomfort of neck and upper extremities and EMG activities in patients with spinal cord injuries. Occupational therapy international, 2019.

Kat aria, J., Sindhu, B., & Pawaria, S. (2020). Effect of mechanical neck pain with forward head posture on scapula position in primary school teachers. Al Ameen J Med Sci, 13, 25–30.

König, J., Jäger-Biela, D. J., & Glutsch, N. (2020). Adapting to online teaching during COVID-19 school closure: Teacher education and teacher competence effects among early career teachers in Germany. European Journal of Teacher Education, 43, 608–622.

Lin, M.-I.B., Hong, R.-H., & Huang, Y.-P. (2020). Influence of virtual keyboard design and usage posture on typing performance and muscle activity during tablet interaction. Ergonomics, 63, 1312–1328.

Merino, G., Da Silva, L., Mattos, D., Guimarães, B., & Merino, E. (2019). Ergonomic evaluation of the musculoskeletal risks in a banana harvesting activity through qualitative and quantitative measures, with emphasis on motion capture (Xsens) and EMG. International Journal of Industrial Ergonomics, 69, 80–89.

Namwongsa, S., Pummetakul, R., Neubert, M. S., & Boucaut, R. (2018). Factors associated with neck disorders among university student smartphone users. Work, 61, 367–378.

Ng, Y. M., Voo, P., & Maakip, I. (2019). Psychosocial factors, depression, and musculoskeletal disorders among teachers. BMC Public Health, 19, 1–10.

Ojukwu, C. P., Anyanwu, G. E., Eze, B., Chukwu, S. C., Onuchukwu, C. L., & Anekwu, E. M. (2018). Prevalence, pattern and correlates of work-related musculoskeletal disorders among teachers in Enugu, Nigeria. International Journal of Occupational Safety and Ergonomics.

Ojukwu, C. P., Ikele, C. N., Nwobodo, O. D., Okemuo, A. J., Ikele, I. T., Uchenw oke, C. I., & Ezeugwu, U. A. (2020). Electromyographic activity of the neck muscles: Effects of varying standing height-derived teaching board heights. Journal of back and musculoskeletal rehabilitation, 1–6.

Park, J.-H., Kang, S.-Y., Lee, S.-G., & Jeon, H.-S. (2017). The effects of smart phone gaming duration on muscle activation and spinal posture: Pilot study. Physiotherapy Theory and Practice, 33, 661–669.

Petronilla, O. C., Amarachukwu, N. C., Justina, O. A., Caesar, C. S., Ikenna, U. C., Moris, A. E., & Jennifer, O. C. (2020). Determining safe teaching board heights through electromyographic analysis of the shoulder muscles. Journal of Bodywork and Movement Therapies, 24, 575–580.

Rota, S., Rogowski, I., Champely, S., & Hautier, C. (2013). Reliability of EMG normalisation methods for upper-limb muscles. Journal of Sports Sciences, 31, 1696–1704.

Sasikumar, V. (2018). A model for predicting the risk of musculoskeletal disorders among computer professionals. International Journal of Occupational Safety and Ergonomics.

Shankar, S., Naveenkumar, R., & Karthick, J. (2019). Management of musculoskeletal shoulder and neck pain through ergonomic intervention: A pre-post design analysis in hand screen printing industry. International Journal of Business Innovation and Research, 18, 392–409.

Shankar, S., Kumar, N., & Hariharan, C. (2021). Ergonomic evaluation of ergonomically designed chalkboard erasers on shoulder and hand-arm muscle activity among college professors. International Journal of Industrial Ergonomics, 84, 103170.

Shinomura, Y., Minowa, K., Kawahira, H., & Katsuura, T. (2016). Ergonomic design and evaluation of the handle for an endoscopic dissector. Ergonomics, 59, 729–734.

Subramaniam, S., Raju, N., Jeganathan, K., & Periyasamy, M. (2018). Evaluation of vibrant muscles over the shoulder region among workers of the hand screen printing industry. International Journal of Occupational Safety and Ergonomics, 24, 278–285.
Subramanian, S., Raju, N., Srinivasan, P., Jeganathan, K., & Jayaraman, S. (2018). Low back pain assessment using surface electromyography among industry workers during the repetitive bending tasks. *International Journal of Human Factors and Ergonomics*, 5, 277–292.

Titheradge, D., Hayes, R., Longdon, B., Allen, K., Price, A., Hansford, L., Nye, E., Ukoumunne, O. C., Byford, S., & Norwich, B. (2019). Psychological distress among primary school teachers: A comparison with clinical and population samples. *Public Health*, 166, 53–56.

Tittiranonda, P., Burastero, S., & Rempel, D. (1999). Risk factors for musculoskeletal disorders among computer users. *Occupational Medicine-Philadelphia*, 14, 17–38.

Van Beek, N., Stegeman, D. F., Jonkers, I., De Korte, C. L., Veeger, D., & Maas, H. (2019). Single finger movements in the aging hand: Changes in finger independence, muscle activation patterns and tendon displacement in older adults. *Experimental Brain Research*, 237, 1141–1154.

Washino, S., Kanehisa, H., & Yoshitake, Y. (2017). Neck inspiratory muscle activation patterns during well-controlled inspiration. *European Journal of Applied Physiology*, 117, 2085–2097.

Wu, F.-G., & Luo, S. (2006). Performance study on touch-pens size in three screen tasks. *Applied Ergonomics*, 37, 149–158.

Yalman, M., & Basaran, B. (2021). Examining PRESERVICE teachers’ use of SMARTBOARD and pc tablets in lessons. *Education and Information Technologies*, 26, 1435–1453.

Zoltan, R. A. G., Magdaș, I. C., & Dulamă, M. E. (2019). Using smart board in preuniversity education in Romania. Proceedings of the 14th International Conference on Virtual Learning, pp. 86–92.

**Publisher’s note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.