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# Postural supporting cervical traction workstation to improve resting state brain activity in digital device users: EEG study

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## Abstract

**Objective:** This study aimed to determine the effect of postural support workstation on inducing effective brain activity during rest.

**Methods:** Thirty-five healthy digital overusers were recruited as participants. We conducted two interventions of head weight support traction (ST) and conventional traction (CT) strength on all participants in random order. Participants' arousal levels and psychological comfort were assessed. In addition, changes in brain activity caused by traction were confirmed by measuring changes in resting state brain activity using an electroencephalogram (EEG).

**Results:** Under the ST condition, psychological comfort improved while alert levels were maintained. In addition the resting brain activity of EEG was characterized by strong focused attention and relaxed activity, as evidenced by increased alpha waves throughout the brain. By contrast, in the CT condition, no significant improvement in comfort was observed. Furthermore, high-frequency brain activity, such as beta 3 and gamma waves, was observed across the entire brain regions.

**Conclusion:** In this study, the ST workstation was shown to effectively improve resting attention and psychological comfort in individuals who excessively use digital devices by inducing resting state alpha activity without stimulating high-frequency brain waves, while maintaining an upright posture with appropriate traction.

## Keywords

Postural support workstations, comfort, focus attention, cervical traction, resting state attention, ergonomics

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## Introduction

As communication through digital media has increased, the use of digital devices has increased rapidly across all generations. Furthermore, the shift from face-to-face operations to work from home schemes in corporate and educational institutions has accelerated the use of digital devices, and Internet service usage rates have increased from 40% to 100% compared with pre-lockdown (COVID-19) levels.[1,2]

These rapid changes have significantly increased the time people spend using digital devices and the total time spent sitting, leading to a surge in diseases related to the use of digital devices, such as visual display terminal (VDT) syndrome.[3] In particular, 75.9% of college students reported that they had experienced musculoskeletal pain

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due to Internet use, with shoulder and neck pain (65%) being the most common.[4] The representative cause of this musculoskeletal pain is postural change (e.g. forward head posture). Compared to neutral posture, forward head posture is not only associated with muscular disorder, but also decreased vertebral blood flow, increased stress, and memory decline.[5–7]

In addition, the potentially harmful cognitive effects of continued digital device use include heightened attention-deficit symptoms, impaired emotional and social intelligence and brain development, and disrupted sleep. Increasing distractions reduce students' focus on learning tasks, general satisfaction, and perceived learning.[8] Therefore, further research is needed to minimize and/or eliminate side effects related to the increased use of digital devices.

The long-term use of digital devices also affects the resting state brain activity. Resting brain function is known to be involved in the essential brain functions, which is supported by the fact that the brain, which accounts for approximately 2% of the body weight, consumes 20% of the total energy with intrinsic activity at rest. In contrast, task-evoked activities are known to use less than 5% of energy reserves, implying a relatively large effect of the resting state brain activity.[9,10]

Importantly, the excessive use of digital devices has been reported to increase functional connectivity between the salience network and the default mode network at rest, resulting in decreased attention and self-control due to the frequent use of digital devices, such as smartphone addiction. In addition, studies have shown that the functional connectivity between the salience and executive networks decreases, causing a decline in cognitive operations.[11]

Furthermore, excessive Internet use can increase the activity of resting state gamma waves, which are associated with an abnormal excitatory system and the hyperarousal of the sensory system, leading to inefficient neural synchrony and functional connectivity.[12,13] In addition, the habitual forward head posture while using the Internet also increases gamma waves throughout the brain compared to the neutral posture since the altered joint position due to forward head posture can affect autonomic and sensorimotor control.[6,14] A previous study also reported that CVA change due to forward head posture had a significant negative correlation with gamma activity.[6] This indicates that forward head posture has a direct effect on brain function, and the prevention of the changes in CVA during computer use through ergonomic environment settings may have a better effect on brain activity. Therefore, interventions are needed for users of excessive digital devices in order to prevent postural change, alleviate fatigue caused by prolonged Internet use, and effectively activate the brain at rest.

Cervical traction is performed using a device that applies physical traction force to the cervical spine. It can be used to treat neck pain and correct spinal curvature by expanding the intervertebral foramen, separating the vertebral bodies, and inducing traction of the posterior joints to exert a therapeutic effect.[15,16] The mechanical traction has significant positive effects on spinal musculature stretching, muscle relaxation, neck pain relief, and postural correction.[15–18]

Cervical traction during computer work has been shown to be an effective intervention for preventing forward head posture and relieving tension in the shoulder and neck muscles caused by the use of digital devices.[19] It has been demonstrated to impact the autonomic nervous system through the activation of the vagus nerve, contributing to the improvement of comfort and working memory ability.[19,20]

However, despite these benefits, the effects of cervical traction interventions on the resting state brain function in heavy digital device users are still poorly understood. Therefore, this study aimed to investigate the effects of cervical traction intervention on brain activity and arousal function in the resting state by measuring the electroencephalogram (EEG) signals and comfort and arousal levels of heavy digital device users to establish a healthy digital device usage environment and to improve cognitive function in daily life.

## Materials and methods

### Participants

The sample size of this study was calculated using G*Power version 3.1.9.4. The effect size was 0.279 based on the results of an internal pilot study on changes in the alpha power spectrum in the resting state according to workstations (partial $\eta^2 = 0.072$). Based on these findings, we calculated a sample size of 35 for the $\alpha$ error probability of 0.05. Considering a potential dropout rate of 10%, three more participants were recruited. To avoid the influence of head posture, participants with a cranio-vertebral angle (CVA) lower than 50° (out of the normal CVA range) were excluded. Additionally, subjects with a history of musculoskeletal, neurological, or psychiatric disorders and subjects who experienced cervical traction or any discomfort that might impact the experiment (e.g. headaches and pain) were excluded from the study. Thus, three participants dropped out due to the exclusion criteria. A total of 35 right-handed healthy adults (18 males, 17 females) aged 20–30 years who used visual display terminal (VDT) for over 4 hours daily participated in this study after providing written informed consent. Demographic information (age, height, weight, and sex) and subjective symptoms during VDT use (eye strain, headache, and neck pain) were collected to investigate general characteristics. Table 1 shows the general characteristics of the study participants. This study was approved by the Institutional Review Board (IRB No. 1044396-202101-HR-015-01) of Gachon University Bioethics Committee and World Health

**Table 1.** General characteristics of participants.

| | Total (n = 35) | Men (n = 18) | Women (n = 17) |
|---|---|---|---|
| Age (years) | 22.29 ± 2.060 | 22.83 ± 2.29 | 21.71 ± 1.60 |
| Height (cm) | 169.92 ± 7.880 | 176.13 ± 5.29 | 162.94 ± 2.86 |
| Weight (kg) | 67.32 ± 11.74 | 74.80 ± 9.05 | 59.40 ± 8.65 |
| Average computer usage period (years) | 11.55 ± 4.26 | 12.13 ± 4.17 | 12.00 ± 3.31 |
| Average daily computer usage time (hours) | 8.40 ± 3.48 | 7.94 ± 3.70 | 7.82 ± 2.81 |
| Subjects who experienced eye strain during work | 28 | 12 | 16 |
| Subjects who experienced headache during work | 16 | 8 | 8 |
| Subjects who experienced neck pain during work | 32 | 16 | 16 |

Organization International Clinical Trials Registry platform (Clinical Research Information Service (CRIS) number: KCT0007814). The participants were directly recruited through flyers posted in public places in Incheon, Republic of Korea from 17 February 2021 to 30 December 2021. No follow-up was performed, and all data were collected in Gachon University. To increase participant compliance, transportation expenses were provided.

## Experimental intervention and protocols

This randomized, controlled crossover study was conducted to investigate the influence of postural head support workstation on electrophysiological functions at rest. All experiments were conducted in a soundproof room equipped with an EEG at Gachon University. An experienced physiotherapist administered the experimental intervention. Two different intervention sessions were performed: head weight support traction (ST) and conventional traction (CT). In the CT condition, which is widely used in the treatment of neck pain, headache, and spinal deformities,[17,18,20] the applied traction force is 10% of the body weight, thus widening the intervertebral foramen and stretching the spinal muscles.[15–17] According to a previous study, 10% traction showed the most effective pain relief and improved neck mobility compared to 7.5% and 15% traction.[21] In contrast, in the ST, the traction force was adjusted to 7.3% of the individual's body weight, which can be assumed by the head weight.[22] In the ST workstation, participants could easily maintain an upright head posture because anti-gravity traction forces replace the function of the cervical spinal extensors. To further ensure a proper application of the head weight support, participants were instructed to relax their neck extensor muscles during the intervention. If the neck extensor is not used, the head naturally falls downward due to the weight of the head. Considering this kinetic process, the subjects were asked to relax their neck extensor muscles, and the physiotherapist directly performed palpation to check muscle relaxation (Figure 1).

For the two different traction interventions in this experiment, we used a TM300 traction system (TM300 Traction System, ITO Co., Tokyo, Japan). We placed the traction belt on the center of the participants' top of the heads to effectively apply the traction force. An adjustable-height chair with a backrest was provided in workstations to maintain their hip and knee joints angle at a 90° while keeping their feet on the ground and leaning on the backrest.[23] To ensure a viewing angle within 10°, an adjustable-height desktop monitor was positioned 60 cm horizontally from the eyes prior to the experiment.[24] Participants were instructed to remain calm and refrain from moving while staring at the center of the monitor. The same experimental settings, including chair height and posture, were used for ST and CT sessions.

The control session was used as a baseline condition. After baseline measurement, the order of the workstations was randomly chosen from the following combinations: (1) ST → CT and (2) CT → ST (Figure 2). During the EEG measurement, participants were asked to gaze at a cross in the center of the monitor (a white letter in a 60-point font size on a black background) without any distractions. Each intervention session lasted for 5 min, and the Karolinska Sleepiness Scale (KSS) and Visual Analog Discomfort Scale (VAS-D) scores were measured as secondary outcomes after each EEG measure concluded.

After all measurements were completed, participants were permitted to take a 5 min break and 5 min rest in sitting before starting the second session to eliminate the

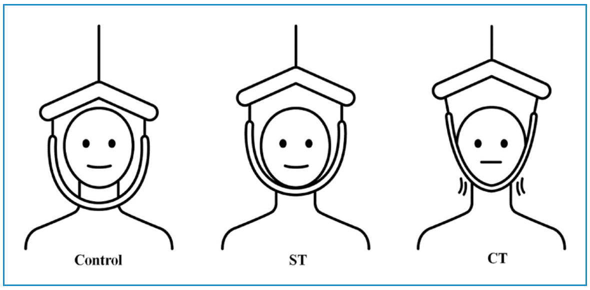

**Figure 1.** Applications of cervical traction in the experiment. ST: head weight support traction; CT: conventional traction.

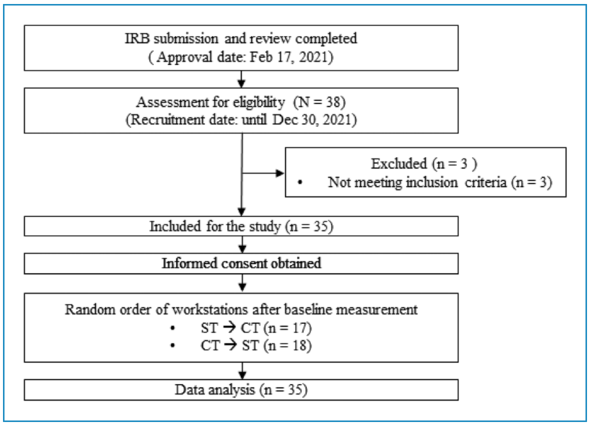

**Figure 2.** Experimental procedure flow chart. ST: head weight support traction; CT: conventional traction.

influence of the previous intervention. Therefore, a total washout time of more than 10 min was provided.

This is based on a previous study, which found no significant difference in blood pressure and heart rate between before and 6 min after cervical traction intervention.[25] Finally, the procedure of the second session was consistently implemented in the subsequent interventions.

## Measures

EEG was conducted with 32 active electrodes (QEEG-32Fx; LAXTHA Inc., Daejeon, Korea) using a 10–20 system. EEG has a sensitivity of 70–94% for detecting brain disorder and is used for various brain diagnoses.[26] Electrodes were placed on the scalp at the following positions: FP1, FPz, FP2, AF3, AF4, AFz, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP1, CP5, CP6, CP2, P7, P3, P4, P8, Pz, O1, Oz, and O2 (see Figure 3). Electrooculogram (EOG) and electrocardiograph (ECG) electrodes were placed on the ventral upper and horizontal sides of both eyes and the left subclavian artery, respectively. All signals were recorded for 5 min using TeleScan software (http://laxtha.net/telescan/). During the EEG recording, the impedances of all electrodes were maintained below 5 kΩ, and a bandpass filter (0.5–50 Hz) was applied online. The electrodes were referenced online to A1 and A2 (A1 + A2), and the 32 electrodes (channels) were classified into the prefrontal, frontal, temporal, parietal, and occipital cortices (Figure 3).[27] Three electrodes (O1, O2, and Oz) were excluded from the analysis due to the traction belt located under the occipital condyle.

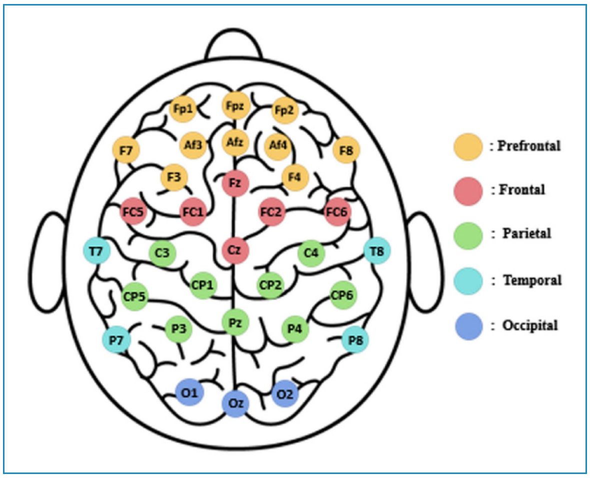

**Figure 3.** EEG electrode locations and brain regions.

To remove the EOG and ECG components, independent component analysis (ICA) was performed using MATLAB-based EEGLAB software.[28] The reference electrode standardization technique (REST) was employed to re-reference the data to the average of all channels.[29] Fast Fourier transform was used to calculate the relative spectral power densities (%) of the delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta 2 (15–20 Hz), beta 3 (18–40 Hz), and gamma (30–50 Hz) waves. The relative power spectral density was computed by the ratio of each wave across the entire frequency range from 0.5 Hz to 50 Hz.

To measure participants' arousal levels, the KSS, a 9-point scale ranging from 1 (extremely alert) to 9 (very sleepful), was employed. Scores were measured immediately after the EEG measurements. Participants were asked to select one of the nine items that indicated their level of awakening.[30] The KSS measures the subjective level of sleepiness at a particular time, and it is known to have a significant correlation ($r = 0.4$) with changes in EEG variables.[30]

Participants reported their comfort levels after each intervention. The VAS-D was used to assess comfort levels and obtained immediately after the completion of the ST and CT conditions. VAS-D scores range from 0 to 10, with 10 indicating "extreme discomfort" and 0 indicating "very comfortable."[31,32] The VAS-D has a moderate correlation with the visual analog scale (VAS) ($r = 0.54$, $p < 0.001$), which is a widely used pain assessment tool.[33]

## Statistical analysis

Following a single-blind procedure, the order of interventions and outcome assessment were blinded during data analysis by a different experimenter. Statistical analysis of the data was conducted using Jamovi ver.2.2.5 (https://www.jamovi.org/). According to the central limit theorem over 30 participants, we have assumed that the data would be normally distributed.[34] Therefore, one-factorial repeated-measures ANOVA (RMANOVA) was used to analyze the mean difference (MD) in each session (Control, ST, and CT) in the KSS, VAS-D, and relative spectral power of EEG. EEG was measured only during the intervention. The KSS and VAS-D were collected only immediately after the intervention. The sphericity test was performed using Mauchly's test. If the sphericity assumption was not assumed, the degrees of freedom were adjusted ($\epsilon > 0.75$ = Huynh–Feldt; $\epsilon < 0.75$ = Greenhouse–Geisser).To determine the corrected probability of the results of the relative spectral power of the EEG, the false discovery rate (FDR) was applied. Post hoc pairwise comparisons were performed using Tukey's honestly significantly different (HSD) test, and the standard criterion of statistical significance ($p < 0.05$) was applied for all analyses. Among the EEG results, only the significant results are shown in the Supplemental tables.

## Results

### VAS-D

The comfort level was significantly influenced by postural support workstation ($p = 0.033$). VAS-D significantly enhanced under the ST condition. Discomfort in the ST condition (VAS-D = 3.06) was significantly decreased by 0.85 compared to the control condition (VAS-D = 3.91, $p = 0.044$) (see Table 2). It also decreased by 0.14 compared to the CT condition (VAS-D = 3.20), but this difference was not significant ($p = 0.947$). Discomfort of CT condition was decreased by 0.71 compared to the control condition, but no significant difference was observed ($p = 0.162$). Therefore, the comfort for workstation was most effective in the ST condition.

### KSS

The workstations had no significant influence on arousal state ($p = 0.174$). The changes in the arousal state due to the postural head support workstations at rest were as follows: the KSS for the ST condition was the highest (control = 3.20, ST = 3.60, and CT = 3.34) (see Table 3). However, there was no significant difference among the three conditions (F = 1.80, $p = 0.174$). For the nine arousal levels, all conditions showed normal arousal levels in the alert state.

### Brain waves

The relative spectral power of EEG signals in the alpha, beta 3, and gamma waves was significantly affected by the postural head support workstations in digital device

**Table 2.** VAS-D differences by intervention.

| Repeated-measure ANOVA | | | | | | Post-hoc comparisons (Tukey) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Dependent variable | Fixed factors | Mean (SD) | F | *p* | $\eta_p^2$ | Variables | | T | *p* |
| | Control | 3.91 (2.02) | | | | Control | ST | 2.51 | 0.044 |
| VAS-D | ST | 3.06 (1.91) | 3.60 | 0.033 | 0.10 | | CT | 1.88 | 0.162 |
| | CT | 3.20 (1.69) | | | | ST | CT | −0.31 | 0.947 |

CT: conventional traction; $\eta_p^2$: partial eta-squared; SD: standard deviation; ST: head weight support traction; VAS-D: visual analog discomfort scale.

**Table 3.** KSS differences by intervention.

| Repeated-measure ANOVA | | | | | | Post-hoc comparisons (Tukey) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Dependent variable | Fixed factors | Mean ± SD | F | *p* | $\eta_p^2$ | Variables | | T | *p* |
| | Control | 3.20 ± 1.43 | | | | Control | ST | −1.87 | 0.163 |
| KSS | ST | 3.60 ± 1.29 | 1.80 | 0.174 | 0.05 | | CT | −0.60 | 0.823 |
| | CT | 3.34 ± 1.11 | | | | ST | CT | 1.39 | 0.357 |

CT: conventional traction; KSS: Kalolinska sleepiness scale; $\eta_p^2$: partial eta-squared; SD: standard deviation; ST: head weight support traction.

users at rest (see Figure 4). The effect of workstations was negligible in the delta, theta, and beta 2 waves. That is, only one or two of 29 channels was significant in those waves, so they were excluded from the further analysis.

In the alpha wave, significant changes were observed in 17 of the 29 electrodes, including the prefrontal (five channels), frontal (two channels), temporal (three channels), and parietal (seven channels) (see Figures 4 and 5).

All channels, except for FP2, showed a significant increase in alpha waves in the ST condition compared to the control, and all channels, except F3 and T8, showed a significant increase in alpha power in the CT condition compared to the control. In addition, in the alpha wave, 14 channels showed a significant increase in both the ST and CT conditions when compared with the control. The channels with large differences between the ST and control conditions in each region included AF4 ($MD = -3.07$, $p = 0.007$) in the prefrontal region, Fz ($MD = -2.73$, $p = 0.001$) in the frontal region, P7 ($MD = -4.36$, $p = 0.002$) in the temporal region, and P3 ($MD = -4.46$, $p = 0.001$) in the parietal region.

In the CT condition, channels with large differences included AF4 ($MD = -3.70$, $p = 0.016$) in the prefrontal region, Fz ($MD = -3.41$, $p = 0.019$) in the frontal region, P8 ($MD = -6.13$, $p = 0.008$) in the temporal region, and Pz ($MD = -6.1$, $p = 0.002$) in the parietal region (see Supplemental Table 1). However, no significant differences were observed between the ST and CT conditions in any channel.

In the beta 3 wave, significant changes were observed in 16 of the 29 channels, including the prefrontal (six channels), frontal (five channels), temporal (one channel), and parietal (four channels) regions (see Figures 4 and 6).

All 16 channels showed a significant increase in the beta 3 wave in the CT condition compared to the control condition. Channels with large differences between the CT and control conditions included AF4 ($MD = -8.23$, $p = 0.005$) in the prefrontal region, FC5 ($MD = -5.14$, $p = 0.026$) in

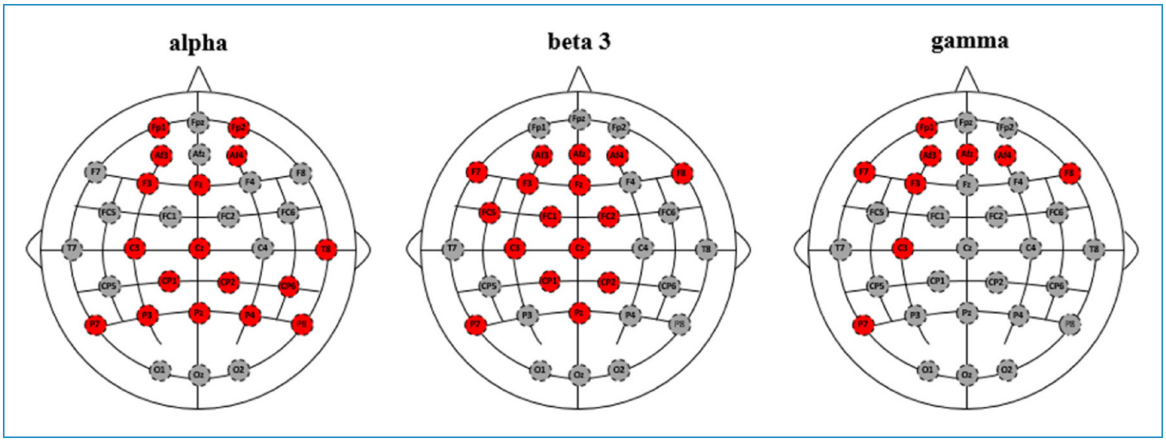

**Figure 4.** Representative result on the EEG electrode locations with significant differences in alpha, beta 3, and gamma waves
The red dots on the EEG map represent the significant channels.

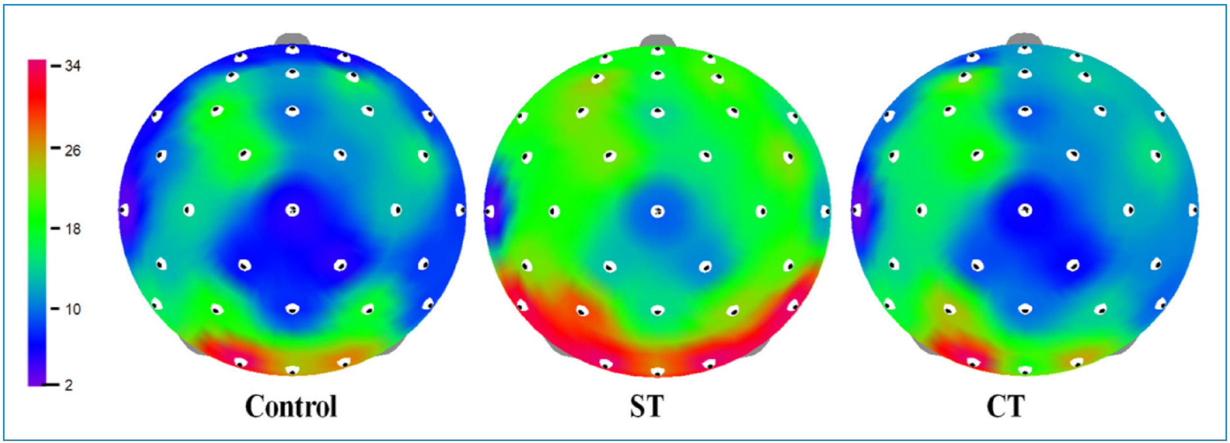

**Figure 5.** Topographies for the differences between intervention methods in the alpha spectral power.
ST: head weight support traction; CT: conventional traction.

the frontal region, P7 (MD = −3.00, $p = 0.041$) in the temporal region, and C3 (MD = −3.84, $p = 0.018$) in the parietal region.

In addition, in the CT condition, the beta 3 waves of the three channels significantly increased compared with the ST condition, including AF4 and F7 (MD = 4.42, $p = 0.038$ and MD = 4.22, $p = 0.039$, respectively) in the prefrontal region and P7 (MD = 2.77, $p = 0.036$) in the temporal region (see Supplemental Table 2). However, no significant differences were observed between the ST and control conditions in any channel.

In the gamma wave, significant changes were observed in nine out of the 29 channels, including the prefrontal, temporal, and parietal regions (see Figures 4 and 7). In the prefrontal region, seven channels, including F3 (MD = 2.57, $p = 0.041$), AF3 (MD = 3.37, $p = 0.015$), AF4 (MD = 4.58, $p = 0.013$), FP1 (MD = 2.59, $p = 0.032$), F8 (MD = 2.87, $p = 0.02$), AFz (MD = 2.20, $p = 0.014$), and F7 (MD = 3.18, $p = 0.023$), significantly increased in the CT condition compared to the control condition.

In addition, the gamma powers of the four channels were significantly higher in the CT condition than in the ST condition, including AF4 and F7 in the prefrontal region (MD = 2.49, $p = 0.048$ and MD = 2.31, $p = 0.037$, respectively), P7 in the temporal region (MD = 1.49, $p = 0.037$), and C3 in the parietal region (MD = 1.55, $p = 0.045$) (see Supplemental Table 3).

## Discussion

In this study, we investigated the effects of the postural head support workstations on the resting state cognitive function (arousal maintenance), psychological comfort, and brain activity (EEG power spectrum).

### *VAS-D*

Both the ST and CT conditions were found to be effective in improving the comfort of digital device users when compared with the control; however, only the ST intervention

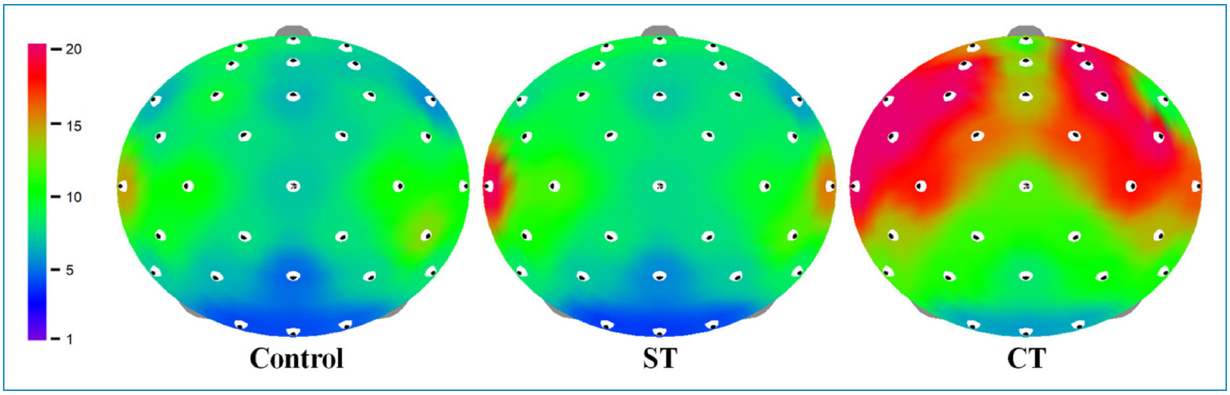

**Figure 6.** Topographies for the differences between intervention methods in the beta 3 spectral power.
ST: head weight support traction; CT: conventional traction.

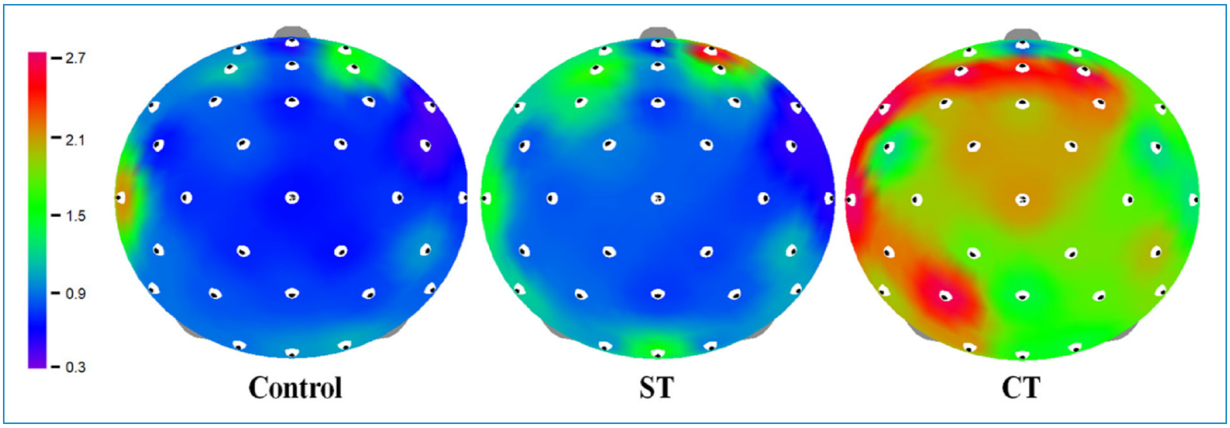

**Figure 7.** Topographies for the differences between intervention methods in the gamma spectral power.
ST: head weight support traction; CT: conventional traction.

showed statistically significant improvements in comfort levels, which may be the impacts of the elimination of mechanical risk factors on long-term digital use.

The head weight on abnormal posture causes the mechanical risk factor because increased compression force and shear force can lead to abnormal muscle hyper and/or hypo tonicity and headache.[35–37] Similarly, in this study, 91% of participants experienced neck pain caused by digital overuse. The ST can effectively eliminate the mechanical risk factor via deweighting of head and holding the head in the right position. Thus, the ST could be applied in improving comfort. In contrast, a previous study has reported that 25% incidence of discomfort feeling appeared in 10% body weight traction force,[20] which means the traction force of CT may have been too strong for some participants. In this study, a significant effect was found with ST compared with the control, indicating that head-holding support is more appropriate than the CT strength. However, these results may be due to the fact that the subjects were healthy adults who did not experience discomfort at levels severe enough to be diagnosed with musculoskeletal disorders and who were unfamiliar with traction interventions.

## KSS

Both the ST and CT interventions had no effect on the reduced arousal state and showed the same average alertness as the control. According to previous studies, the higher the body support area and the greater the pressure distribution, the better the posture for sleeping.[38,39] Therefore, in general, the resting posture involves lying down or reclining in a seated posture so that the musculoskeletal system receives sufficient support, thereby relaxing the muscle tone and reducing muscular activity, which promotes sleep and reduces arousal.

In this study, although the ST or CT condition with head support or traction could potentially reduce arousal levels compared to the control in an upright posture, no significant differences in arousal states were observed. This can be attributed to the fact that, during cervical traction, the minimal muscle tone is required to maintain an upright posture and a smaller area is involved to support the head's weight.

As demonstrated in various studies of the effects of embodiment cognition on physiology and subsequent behavioral choices, an upright posture can cause emotional, psychological, and behavioral changes.[40–42] Therefore, postural manipulation can positively affect mood and energy and improve arousal levels.[41,43] The results of the present study likewise suggest that postural manipulation through cervical traction may affect the maintenance of arousal levels.

## Brain waves

Increased alpha wave activity was observed throughout all regions of the brain under both the ST and CT conditions. In general, increased alpha activity is related to relaxation and focused attention, and alpha oscillations dominate relaxed arousal states.[44] Increased alpha activity is also related to meditation, which induces physiological relaxation responses, leading to increased cerebral blood flow in the prefrontal, inferior frontal, and postcentral regions and increased alpha activity in the prefrontal, frontal, and parietal regions.[44–47] Thus, the effects of cervical traction on postural support, head support, and physical relaxation may influence the increased alpha activity resulting from ST and CT. Head support has been reported to be effective in correcting forward head posture and relaxing suboccipital muscles.[19]

A significant increase in high-frequency activity was observed only under the CT condition. Passive stretching due to sufficient traction strength on CT can increase cervical muscle, joints, and spinal cord stress. According to previous studies, abnormal sensory input to the cervical joints and spinal cord due to excessive external force (e.g. pressure and stretch) contributes to spine-related autonomic dysfunction.[14,48] Therefore, this dysfunction occurs because it affects parasympathetic organs, such as the brainstem and cranial nerve 10, that is, increase in sympathetic tone and decrease in parasympathetic tone.[14] The sympathetic activity is known to be associated with high-frequency brain activity. Increased high-frequency brain activity (ex, gamma) has been observed in forward head posture, which is related to increased sympathetic tone.[6] Therefore, we considered that the traction force applied to cervical joints may influence to increase beta 3 and gamma activity. In addition, the response to traction in the muscular and sensory systems can affect beta 3 and gamma waves. Beta 3 activity is associated with corticomuscular coherence,[49–51] and gamma activity is linked to a perception of hypersensory input, such as pain.[52] Therefore, the resting brain function can be interrupted by a significant increase in beta 3 and gamma waves. Conventionally, high-frequency waves have been associated with high brain activity. Increased beta 3 activity at rest indicates unnecessary arousal, which reflects cortical hyperexcitability and can affect the overall level of neural excitation.[50,53,54] In addition, high-frequency brain waves that appear throughout the entire brain, such as beta 3 and gamma waves, are positively correlated with inattention levels.[55,56] Therefore, increased high-frequency waves resulting from CT are likely to induce distraction in the resting state. In addition, gamma waves are associated with cortical activation related to sensory information and are known to increase as the perceived stimulus intensity rises.[52] Similar to previous results, the increased gamma activity in the CT condition seems to be affected by increased traction sensory stimulation. Previous studies also reported that the greater traction forces result in the greater neck tightness and discomfort.[20] Thus, it was confirmed that the appearance of high-frequency brain activity (beta 3 and gamma) only in the CT session suggests that even the lowest intensities used in clinical practice have excessive effects on brain activity. Therefore, CT has shown a less adequate effect than head weight support traction (ST) on resting brain activity because high-frequency brain activity interferes with adequate brain rest. In addition, CT may aggravate heavy internet users who exhibit abnormal excitatory systems at rest since they typically exhibit high gamma activity during rest.[12,13]

Consequently, implementing equipments to assists head weight and posture in the office environments will help to mitigate muscular fatigue and promote cognitive relaxation among digital device users. With the introduction of this equipment, therefore, office workers may experience reduced muscle fatigue and achieve improved concentration and productivity throughout the workday.

Furthermore, excessive internet use can increase the activity of resting state gamma waves, which are associated with an abnormal excitatory system and hyperarousal of the sensory system, leading to inefficient neural synchrony and functional connectivity.[12,13]

## Conclusion

This study examined the effects of postural head support workstations on brain activity and psychological state during rest. We found that neither the ST nor the CT intervention significantly altered participants' arousal levels as they maintained an alert state. Additionally, their comfort level significantly improved only in the ST condition compared to the control condition.

Furthermore, the alpha wave activity associated with relaxation and focused attention increased in both the ST and CT conditions across all brain regions, including the prefrontal, frontal, temporal, and parietal areas. However, under the CT condition, excessive sensory stimulation resulted in abnormal brain activity with increased high-frequency waves, indicating cortical hyperexcitability. Thus, CT is a less suitable intervention than ST for resting state brain activity. This is because high-frequency waves can interfere with proper brain rest.

In sum, we found that appropriate postural support had the potential to enhance comfort and alpha wave activity without stimulating high-frequency brain waves in excessive digital device users. Increased alpha wave activity during rest may help reduce distractions and improve attention focus in individuals who overuse digital devices.

## Limitations

In contrast, low-frequency waves, including delta and theta waves, did not significantly change among the conditions. Delta and theta waves are associated with sleep, decreased alertness, and drowsiness.[57] Consistent with the KSS results, neither the ST nor the CT condition induced sleep or drowsiness. Considering the changes in the psychological state and cortical activity in alpha, beta 3, and gamma waves during interventions, ST increases alpha wave activity and is associated with relaxation and focused attention, but does not affect inappropriate high frequencies during rest. Therefore, ST is a more effective intervention than CT for resting brain activity among excessive digital device users. Further research will be needed to confirm the cut off intensity at which any side effects occur and to confirm the optimal traction force for enhancing brain activity.

This study examined the effects of postural head support workstations on brain function during rest in excessive digital device users. However, participants were all healthy adults, and these digital device overusers had not been officially diagnosed with digital addiction; therefore, it is difficult to determine whether the same effects would be observed in other clinical groups, such as diagnosed digital addicts and individuals with musculoskeletal disorders or chronic pain. Therefore, it is necessary to investigate the effects of cervical traction on the recovery of brain function at rest in individuals diagnosed with digital addiction. Additionally, further research needs to consider potential confounding factors, such as pain sensitivity, postural habits, and physical activity level for a more comprehensive analysis. In addition, because we focused on the effects of traction on brain function, it was difficult to confirm the post-intervention effects. Furthermore, the present study applied 5 min of continuous traction intervention in each session; thus, we cannot confirm the long-term and intermittent traction effects. Although intermittent cervical traction is a well-known treatment option for neck pain, the post-effects on resting brain function and psychological state after various technical advances in traction interventions need to be examined in further studies.

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**Data availability:** The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

**Declaration of conflicting interests:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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