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Original Research Article

Immediate effect of virtual reality intervention on task related neck pain and muscle fatigue in dentists

Shabarish Menon[1], Twinkle Dabholkar[1], Isha Shripad[2]*

[1]Department of Musculoskeletal Physiotherapy, D. Y. Patil Deemed to be University, School of Physiotherapy, Nerul, Navi Mumbai, Maharashtra, India
[2]Cardiovascular and Respiratory Department, St. Andrews College of Physiotherapy, Pune, Maharashtra, India

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***Correspondence:**
Dr. Isha Shripad,
E-mail: drishashripad@gmail.com

ABSTRACT

Background: Dentistry requires long hours of static body postures while executing activities in which permanently forced loads influence the musculoskeletal system.
Methods: 25 dentists were recruited where neck pain or fatigue was assessed subjectively using NRS and Borg CR10 scale respectively and the pain pressure threshold of the upper trapezius muscle was assessed objectively using a handheld algometer pre- and post- intervention. Mobile VR game- Froggy VR was administered as a virtual reality.
Results: A Wilcoxon signed rank test showed a statistically significant reduction in the intensity of task related neck pain and fatigue post VR intervention with Z-score=-4.549, n=38, p<0.001 and Z-score=-4.588, n=38, p<0.001 respectively. Also, there was a statistically significant increase in the pain pressure threshold of the right and left upper trapezius muscle post VR intervention with Z-score=-4.937, n=38, p<0.001 and Z-score=-4.512, n=38, p<0.001 respectively.
Conclusions: Virtual reality intervention led to an immediate reduction in task-related neck pain and muscle fatigue among dentists with an immediate reduction in pain sensitivity of the upper trapezius muscle in dentists.

Keywords: Pain pressure threshold, Task specific neck pain, Virtual reality intervention

INTRODUCTION

Dentistry is one of the professions which involve strenuous preparations which require high levels of finesse, precision and control in executing as well as concentration and patience of the dentist and their physical and mental toughness. A major part of dentists' work involves awkward positions mainly pertaining to static positions of trunk and head.[1] There are numerous instances where dentists have deviated from an ideal ergonomic working style and work in an incorrect posture for reasons such as habitude, working routine and poorly designed workstations. The relationship between the body of the dentist and various elements of his workstation influences the working posture of the dentist, to the extent that his/her posture is affected by an incorrectly designed or used workstation. All the spatial and environmental elements with which the dentist interacts with while working are included in workstation.[2] Thus, the working posture of the dentist is one of the most discussed themes in the field of ergonomics applied in dentistry. Ideal posture of a dentist provides him optimal working conditions (access, visibility and control in mouth) with physical and mental comfort while carrying out clinical acts. Ideal posture provides dentist increased work energy levels, more comfort, reduced stress and pain whereas faulty posture causes early fatigue, pain, stress and a bad attitude towards work increasing his risk for musculoskeletal disorders in the future (defined as per "ISO standard 11226 ergonomics- evaluations of static operating postures").

Prevalence of neck pain among dentists in India is from 56-72% according to the studies conducted by Magdalene et al, Shinde et al and Prudhvi et al.[3-5] A study conducted by Feng et al on prevalence of work-related musculoskeletal symptoms of the neck and upper extremity among dentists in China reported 88% dentists to have at least one musculoskeletal disorder and 83.8% suffered from neck pain.[6] Another study by Alexopoulos on prevalence of musculoskeletal disorders in dentists identified the neck to be the second most problematic area reported in dentists following back and trunk.[7] This might be due to ideal posture of dentist adopting forward inclination of head up to 20-25 degrees from trunk, and with many dentists adopting faulty postures at neck during treatment as seen by area of cervical spine the 75th percentile showing worse angular values during treatment than during non-dental tasks.[1,2]

Static body postures are commonly seen while executing dentists' activities in which permanently forced loads influence the musculoskeletal system. Moreover, the posture and movement capabilities of the dentist are limited or defined.[7] The movement versatility or scope of movement is low. Many of the constrained postures in dentists in awkward angle value positions in particular in the head-trunk area, can be observed. While working, these postures need to be maintained for longer period. For example, there is anterior tilting of the entire head and trunk area and static positions are maintained for more than 4-10 seconds. A posture that is being held for more than 4 seconds, in occupational science, is defined as a static body posture (ISO standard 11226 ergonomics-evaluations of static operating postures). Long working hours in static positions mostly in faulty work postures without long breaks as well as recurrent and repetitive movements attribute to musculoskeletal disorders in dentists.[7]

Figure 1: Dental procedures performed by the dentists in a neck bent posture

Virtual reality (VR) is an interface that provides a computerized immersive simulation of a real and three-dimensional environment. VR helps the individual to interact with multisensory experiences through the tracking of the head movement. VR comprises the three basic elements: immersion, interaction and engaging. Immersion is the sensation of being totally within an environment, interaction is the way the individual reacts according to the presented VR stimulus and engaging is the degree of involvement of the user with the stimulus.[8] Multisensory experiences in a virtual environment influence the emotional processing of the brain and consequently of pain and the autonomous nervous system (ANS). Few studies suggested that the emotional stimuli can influence the perception of pain, involving descendant modulatory paths, indicating that the positive emotions diminish the perception of pain, whereas negative emotions that trigger stimuli can increase the intensity of pain.[9] Nowadays, the evolution of technology, the greater availability of videos and the reduction of the costs of VR devices have allowed the popularization and expansion of their use for entertainment, work situations and health applications.[10-12]

Attention of researchers has been gradually increasing in the application of virtual reality (VR) games in the field of medical rehabilitation training. A VR device for assessing neck kinematics has been developed by researchers with the said device having been proved a useful and reliable evaluation tool for neck pain.[13] It is also an effective training tool. Experiments have proven that VR can successfully decrease anxiety and pain, stimulate physical activity, and increase the effectiveness of exercise compliance.[14] Immersion is one of the concepts that allow VR environment to distract the patients. When immersion is high, the user's attention is centered on the virtual environment, causing distraction from other things, such as pain. Cervical kinematic training can improve chronic neck pain with and without interactive VR training. But since VR can interact and potentially dispel pain and anxiety, VR training is considered better to improve these factors.[15]

There are a very few studies addressing the task related pain in dentists as it is one of the factors which could affect their productivity, increase fatigue, and limit their capability for working long hours causing a temporary activity limitation. VR creates a non-pharmacologic form of analgesia by altering the activity of the body's intricate pain modulation system.[14] As VR provides a portable and easy to use intervention which could be easily administered; this study was performed to find out whether VR gaming intervention has an effect on reducing task related neck pain and muscle fatigue.[16]

METHODS

In the first phase of our quasi-experimental study, we conducted a pilot study in which a questionnaire was administered to 29 dentists to identify the dental tasks which required sustained neck flexion, hours spent in neck flexion, duration of working in sustained neck flexion after which there is onset of fatigue, and to see whether dentists reported pain and fatigue differently.

It was found that 65.5% dentists suffered from neck muscle fatigue while on job and 51.7% dentists reported task related neck pain, with the dentists reporting both symptoms differently. 84% dentists reported the pain to be intermittent with onset post activity and relief within 24 hours. Based on the collected data, the inclusion and exclusion criteria were devised.

Ethical approval for the study was obtained from the institutional ethics committee (IEC). As per the National Ethical Guidelines for Biomedical and Health Research involving Human Participants, ICMR 2017 our study involved a risk category of 'minimum risk'. Participants included both male and female dentists in the age group of 22-37 years, working in a clinical setting for more than 1 year and postgraduate dental students. The sampling method used was convenient sampling method. The sample size was calculated using the data from our pilot study.

Inclusion criteria

The inclusion criteria included dentists who were currently practicing for more than 1 year, participants experiencing neck pain or fatigue during dental tasks that involves sustained flexion and intermittent pain or pain after activity that subsides after 24 hours (less than 4 on NRS).

Exclusion criteria

Patients who experienced continuous pain, signs of radiculopathy, underwent recent surgery, tumor or infection of cervical spine, symptomatic cervical disc prolapse, spondylolisthesis, spondylosis, rheumatoid arthritis, vestibular pathologies (e.g. vertigo, dizziness), ear infections, hearing loss, ear ringing (tinnitus), somatosensory defects from stroke, cerebral palsy, brain injury and motion sickness were excluded from the study.

The study duration was 18 months, from December 2020 till June 2022.

Dentists with task related neck pain or neck muscle fatigue, while working, were included in the study via convenience sampling. All participants were provided with written informed consent prior to their enrollment. Participants who provided consent and fulfilled the inclusion criteria were recruited in the study. A total of 38 dentists were recruited for our study. Participants were required to fill out a questionnaire which consisted of demographic information, job requirements, level of task related neck pain, muscle fatigue and duration of working after which there is onset of pain or fatigue, prior to taking part in study.

On the day prior to the intervention, the participants were familiarized with the VR training device for 2 minutes to rule out any discomfort or problems they would face during the procedure. Before the intervention, each participant was explained the complete procedure of the experiment, and was familiarized with the requirements and precautions of the intervention such as the researcher had to make sure that the participant is comfortably seated and does not fall down from the chair while in the virtual environment; or that the participant while in the VR environment is required only to move the neck and not the chair in order to play the game. Based on the information provided by the participant on the onset of neck pain or fatigue, VR intervention was administered to the participant after the participant had worked for at least 40.14±22.72 minutes immediately after the onset of neck pain or fatigue (Table 1).

Initially when the participant started experiencing neck pain or fatigue, the severity of the pain and fatigue was assessed subjectively using NRS and Borg CR10 scale respectively, and the PPT of the upper trapezius muscle was assessed objectively using a handheld algometer. After obtaining this baseline evaluation of the participants the VR intervention was administered, during which the participants were required to play the VR neck game for 5 minutes at their own work station.[13,15]

Figure 2: Handheld pressure algometer.

Figure 3: VR box® headset.

Virtual reality intervention

Mobile VR game- Froggy VR was administered to the participants.[17] It is a casual VR adventure scenario game. In Froggy VR, the player played as a frog on the way to rescue the princess. In the game, the player needed to move his/her head in different directions to perform various tasks in the game. The movements included flexion, extension, side flexion and rotation of the neck.[17]

Figure 4: Participant while performing VR intervention.

Immediately after the intervention the participant was given one minute to get reoriented to his normal environment after coming out of the virtual environment. Following this, the severity of neck pain and fatigue as well as the pain pressure threshold (PPT) of the upper trapezius muscle was assessed to evaluate for the effect of the VR intervention on the levels of neck pain, fatigue and the PPT of the participant.

RESULTS

38 participants (M=15, F=23) were recruited in the study. The demographic details for these participants included age, gender and dominance. The work-related information or job description such as duration of working hours, duration spent in neck flexed in hours was also recorded. The age distribution in the study population of 38 was 26±2.57 with a gender distribution of 12:23 (M:F), or 12 males and 26 females. 8 of the participants were left-handed, whereas the other 30 were right-handed. The mean work experience of the participants was 3.21±2.06 years. The participants' average working hour duration was 4.42±0.72 hours of working. The mean duration spent in neck flexed posture while working was 4.42±0.72 hours. The mean duration spent working prior to onset of pain or fatigue was 40.14±22.72 minutes.

Table 1: Mean and standard deviation of pain (NRPS), fatigue (Bord CR 10 scale) and pain pressure threshold of right and left trapezius muscle (using handheld algometer) pre and post intervention.

Outcome measures		N	Mean	Std. deviation	Minimum	Maximum
Pain (NPRS)	Pre intervention	38	3.2632	1.22329	0.00	4.00
	Post intervention	38	2.1316	1.27705	0.00	4.00
Fatigue (Borg CR 10 scale)	Pre intervention	38	4.5263	2.67861	0.00	9.00
	Post intervention	38	2.7895	2.15805	0.00	7.00
Pain pressure threshold (right trapezius muscle)	Pre intervention	38	3.0961	1.03509	1.30	5.60
	Post intervention	38	3.8434	1.08355	2.50	6.80
Pain pressure threshold (left trapezius muscle)	Pre intervention	38	3.5092	1.28114	1.30	6.70
	Post intervention	38	4.3961	1.43142	2.30	8.10

Table 2: Wilcoxon signed rank test for pain (NRPS), fatigue (Bord CR 10 scale) and pain pressure threshold of right and left trapezius muscle (using handheld algometer) pre and post intervention.

Outcome measures	Z	Asymp. Sig. (2-tailed)
Pain (NPRS)	-4.549	<0.001
Fatigue (Borg CR 10 scale)	-4.588	<0.001
Pain pressure threshold right trapezius muscle)	-4.937	<0.001
Pain pressure threshold left trapezius muscle)	-4.512	<0.001

Statistical analysis of outcome measures

Difference between pre and post-intervention pain intensity on numerical pain rating scale

Interpretation

A Wilcoxon signed rank test was computed to assess the change in the intensity of pain post intervention. There was a statistically significant reduction in the intensity of task related neck pain post virtual reality intervention with Z-score=-4.549, n=38, p<0.001 with α at 0.05 (Figure 5).

Difference between pre and post-intervention fatigue intensity on Borg CR10 RPE rating scale

Interpretation

A Wilcoxon signed rank test was computed to assess the change in the level of neck fatigue post intervention. There was a statistically significant reduction in the level of neck fatigue post virtual reality intervention with Z-score=-4.588, n=38, p<0.001 with α at 0.05 (Figure 6).

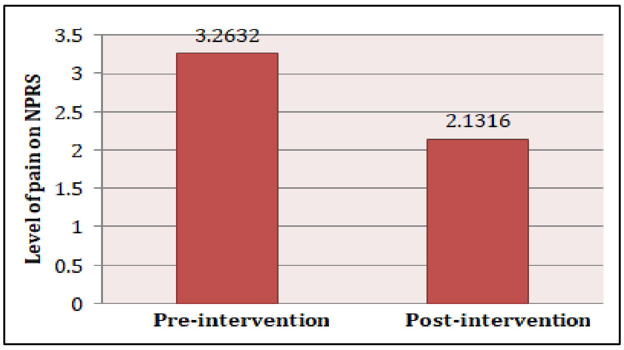

Figure 5: Graphical representation of mean and standard deviation of NRPS pre and post intervention.

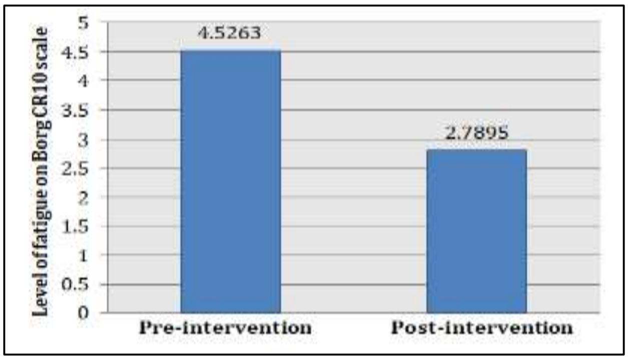

Figure 6: Graphical representation of mean and standard deviation of Borg CR 10 scale pre and post intervention.

Difference between pre and post-intervention PPT of right upper trapezius muscle by handheld algometer

Interpretation

A Wilcoxon signed rank test was computed to assess the change in the pain sensitivity evaluated by pain pressure threshold of the right upper trapezius muscle post intervention. There was a statistically significant increase in the pain pressure threshold of the right upper trapezius muscle post virtual reality intervention with Z-score=-4.937, n=38, p<0.001 with α at 0.05 (Figure 7).

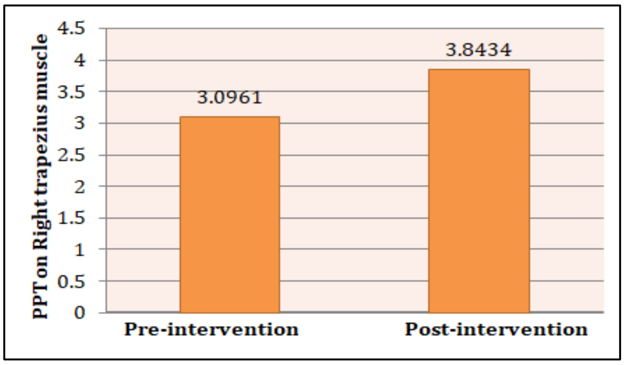

Figure 7: Graphical representation of mean and standard deviation of pain pressure threshold of right upper trapezius muscle pre and post intervention.

Difference between pre and post-intervention PPT of left upper trapezius muscle by handheld algometer

Interpretation

A Wilcoxon signed rank test was computed to assess the change in the pain sensitivity evaluated by pain pressure threshold of the left upper trapezius muscle post intervention. There was a statistically significant increase in the pain pressure threshold of the left upper trapezius muscle post virtual reality intervention with Z-score=4.512, n=38, p<0.001 with α at 0.05 (Figure 8).

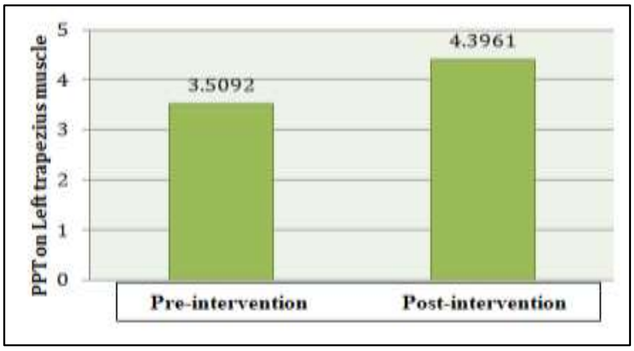

Figure 8: Graphical representation of mean and standard deviation of pain pressure threshold of left trapezius muscle pre and post intervention.

DISCUSSION

This quasi-experimental study was conducted to assess the immediate effect of a single VR intervention in dentists reporting activity/task related pain and fatigue. The assessment parameters were neck pain, neck muscle fatigue and pain pressure threshold of both the left and right upper trapezius muscle. Participants who met the inclusion criteria between the age group of 22 to 37 years were included in our study. The mean±SD age of the participants was 26.31±2.57. They were asked to perform their usual dental tasks at their own workstation prior to the onset of pain. After reporting the onset of pain which was on average after 40.14±22.72 minutes of working (Table 1), a pre- intervention assessment was done to obtain the baseline pain, fatigue and pain pressure threshold values. VR gaming intervention was administered for 5 minutes to the participants at their own workstation which involved games that operate through goal-directed gentle neck movements in an immersive.[17] Post-intervention assessment of pain, fatigue and pain pressure threshold was carried out immediately after the cessation of the intervention. Our results indicate significant improvement on all outcome measures including task related pain, fatigue and pain pressure threshold of both the right and left upper trapezius muscle. Although our sampling method was convenience sampling, male to female (M:F) participants ratio in our study was 12:26 indicating more female participants. Paksaichol et al, conducted a review of 7 independent cohorts (5 rated high quality) and their results indicated that female gender were strong risk factors for acute neck pain.[18] No studies were conducted for task related pain, yet we found a predominance of female gender reporting these symptoms in our study. We aimed to assess the immediate effect of VR intervention on task related pain and muscle fatigue in dentists.

Virtual reality being a novel approach provided a simulation-based 3D immersive environment which helped the individual gain an interactive, engaging and pleasurable experience.[8] With the inclusion of the gaming component, it best served to engage the individual with impairment in purposeful activity. As a result of it being a goal-oriented intervention, when opposed to a passive intervention such as passive stretching or myofascial release, VR needed an active engagement from the volunteers, who were more involved in the therapy process. For these reasons VR was chosen as an intervention in our study.

Effect of VR on neck pain

We included dentists with no pain at rest and who reported pain post activity (NPRS<4 points on 11-point scale). The mean activity related pain reported by our study participants was mild i.e. 3.2 points. Post VR intervention our study participants reported an immediate reduction in the intensity of neck pain by 1.1 points on NPRS, which was a statistically significant change (Figure 5, Table 2 and Table 3). Cleland et al reported the MDC and minimal clinically important difference (MCID) were 1.3 and 2.1 points respectively, where participants rated the intensity of their cervical pain at rest on an 11-point numeric pain rating scale (0-10, with 0 as no pain and 10 as maximum pain) in self-reported neck pain.[19] A study conducted by Kovacs et al concluded that MCS was higher for patients with more intense baseline pain (pain above 6 on NRS) ranging from 2.4 to 4.9 PI-NRS for neck pain (without referred pain) and from 2.4 to 5.3 for referred pain. Also, improvements ≤1.5 PI-NRS points could be seen as irrelevant as the cutoff point for clinical relevance depends on the methods used to estimate MCIC and on the patient's baseline severity of pain.[20] In our study we found significant difference in the pain reported pre and post intervention by the participants but could not surpass the MCID of 1.5 (Kovacs et al).[20] This could be owing to the inclusion criteria of the study which focused on the task related pain which was intermittent in nature (subsided within 24 hours) i.e. the participants did not report symptomatic pain whereas the above mentioned published studies have included patients with symptomatic pain disorder. Another reason might be the single-session study design, in which the intervention was administered only once, and only the immediate effect of the VR intervention was examined, with no further evaluation on subsequent days to check for the intervention's long-term effects.

The reason for statistically significant reduction in neck pain can be postulated to the following reasons:

Distraction/diversion of attention

Virtual reality training provides an immersive environment which works as a distraction. As the individual is allured in the gaming adventure, it increases the positive experience by modulating pain at the level of ANS by influencing the emotional processing of the brain. These emotional stimuli work as a trigger to positive emotion thus improving the perception of pain.[9] Silva et al also concluded in their study, that individuals who submitted to VR nature would present a greater vagal predominance and that VR had an effect on ANS independently because of the emotional regulation promoted by attention. That is, emotional regulation in the presence of an attentive task involves a network composed of the lateral prefrontal cortices, temporal and parietal regions, as well as the supplementary motor area and the cingulate cortex.[21] Gold et al explored further on this neurobiology of virtual reality pain attenuation. They stated that immersive VR diverted attention from an unpleasant setting such as pain to a pleasant and absorbing virtual world while engaging higher cognitive and emotional centers of the nervous system, in this way VR can markedly diminish a patient's subjective pain experience. They added that under normal conditions pain is detected by nociceptors located throughout the body, nociceptors relay the information to the CNS via A-delta and C fibers. Both fibers make their first synapse in the dorsal horn of the spinal cord, then cross at the midline and ascend in the spinal thalamic tract, and then terminate in the thalamus. At the level of the brain, pain fibers innervate various cortical regions, including the primary and secondary somatosensory cortices, the anterior cingulate cortex (ACC), areas of limbic system, and the insular cortex. By acting directly and indirectly on pain perception and signaling through attention, emotion, concentration, memory and other senses (auditory, visual), VR may change the activity of the body's intricate pain modulation system, thus altering pain perception. The perigenual ACC, a structure known to mediate attentional and emotional processes, is activated by VR. The ACC then activates the PAG which in turn initiates a cascade of signaling events to stimulate the descending pain-modulation system and produce analgesia.[22]

Pourmand et al conducted a study using clinical trials on Virtual reality as a clinical tool for pain management. He concluded that VR therapies can effectively distract patients who suffer from chronic as well as acute pain stimulated in trials.[11] A systematic review and meta-analysis conducted by Mallari et al consisted of twenty experimental and quasi experimental trials which aimed to compare the effectiveness of VR in reducing acute and chronic pain in adults. This study provided an updated systematic literature review showing the effects of VR on acute pain and concluded that VR is an effective tool in reducing acute pain both during and post immediate VR exposure time frame.[23] Another systematic review and meta-analysis by Ahern et al included seven

RCTs to review the effectiveness of VR in patients with spinal pain. It was found that VR training showed improvement in the global perceived effect (GPE) and level of satisfaction in chronic neck pain patients. It also reduced pain intensity and disability experienced at short-term and long-term follow-up compared to conventional proprioceptive training in patients with chronic neck pain.[24] The study population used in this study had patients with chronic neck pain and took a long term follow up while comparing VR with conventional training, in our study we have included participants with task specific neck pain brought on by sustained posture focusing more on the immediate effects of the VR gaming intervention.

Placebo

In her study Colloca described how the clinical outcomes of pain therapies were modulated by the placebo effect. She attributed the effect to psycho-neurobiological changes brought on by verbal suggestions (e.g., anticipating a benefit), firsthand therapeutic experience of pain reduction (e.g., experiential learning and conditioning), interpersonal interactions (e.g., client-clinician relationship), environmental and treatment cues (e.g., witnessing a treatment), and observation of others (e.g., social learning).[25] Colloca in another study, along with Klinger et al elaborated on the psychological and neurobiological mechanisms of placebo analgesia. They described how at the neural levels, placebo effects result in the release of neuropeptides (e.g., opioids) and the modulation of brain areas involved in the transmission of pain signaling and the formation of expectancies. When placeboeffects are evident, areas such as the spinal cord, RVM, PAG, mThal, ACC, SII-dpINS, and aINS exhibit reduced activation. Expectancies are generated by enhanced frontal activation, including the vmPFC and dlPFC, as well as descending modulation of the NAc-VS, PAG, spinal cord, and RVM. PAG, the spinal cord, and RVM play a dual function with both increased and decreased activity. They concluded that the generated placebo effects influence responses to pharmacological, integrative, psychological, and surgical interventions.[25,26]

Because our study used a quasi-experimental design, there was no need for a control group, and the effect of placebo was not negated. As a result, the pain reduction after VR intervention in our study might be due to the placebo effect.

Effect of VR intervention on neck fatigue

We included dentists who reported neck fatigue or rate of perceived exertion (RPE) post activity on the Borg CR10 scale. The mean fatigue post activity reported by our study participants was one and a half point more than moderate on the scale i.e. 4.5 points. Post VR intervention our study participants reported an immediate reductionin the RPE or level of neck fatigue by 1.8 points on the Borg CR10 scale which was a statistically significant change (Figure 6, Table 4, and Table 5). Borg CR10 scale was used as an assessment tool for measuring neck muscle fatigue or rate of perceived exertion of the participant during or after completion of dental.[27,28] As the study was carried out in the clinical setting where the dentists performed the tasks at their own workstation; and VR intervention was given immediately after the participants experienced fatigue brought on by performing dental tasks, at their own workstation; Borg CR10 scale was a more feasible tool when compared to EMG for assessing fatigue given the study setting.

In a study conducted by Song et al, it was found that when the behavior of head turning adopted by neck pain patients to relieve neck fatigue was gamified, it leads to an increased degree of interest in participants and proved beneficial to distract their attention, increase their pleasure degree, and then generate positive feedback on the perception of neck fatigue. The study also found that the game design itself is essential and plays an important role in creating and engaging aninteractive simulation.[17]

Another factor which plays an important role in reducing neck fatigue in professions which involve maintenance of static postures, is ergonomically advised breaks between working. Low effort activities such as meditation, a short nap, a small walk and stretching are effective in providing relaxation during these breaks. In this way regularly changing the head and neck position is an important strategy for shifting the muscle workload from one area to the other, to reduce fatigue.[29] VR Intervention was delivered for 5 minutes after the pain/fatigue due to sustained repetitive activity started to set in, which was on average about 40.14±22.72 minutes (Table 1) of performing dental tasks, the VR intervention helped shift the muscle workload from one area to the other and reduced fatigue following the intervention. The inclusion of the gaming component provided a recreational activity for the participants with a therapeutic benefit. In our study, we found significant reduction in fatigue with VR intervention (Figure 7, Table 4 and Table 5). Thus, we suggest VR gaming as an alternative activity that can be performed by the dentists' in between continuousworking for long hours, to help reduce fatigue.

A study conducted by Montoya et al evaluated the effects of using bio-cybernetic adaptation in a virtual rehabilitation game where surface-electromyography (sEMG) signals were used to detect fatigue levels. The participants were subjected to two different visualization modalities: non- immersive (conventional flat screen) and immersive (VR headset). Results revealed that the immersive environment produced lower levels of perceived fatigue and created a more enjoyable and positive experience in a controlled experiment compared with the non-immersive. Furthermore, when compared to the non-immersive condition, participants in the immersive condition performedbetter in the virtual game and received higher usability ratings from users. This study highlighted the role of combining novel immersive approaches with physiologically aware systems to enhance the benefits of virtual rehabilitation therapies.[30]

Similarly a study conducted by Song et al assessed whether the VR game and the AR game have an impact on neck muscle fatigue and compared the degree of influence. The neck muscle fatigue was induced by making the participant play a mobile game for 30 minutes in neck flexed posture. The neck muscle fatigue was measured using integrated electromyography (IEMG) for the upper trapezius, splenius cervical muscles, and sternocleidomastoidmuscles. The results showed that both the VR group and the AR group provided cervical relief and the VR game could better alleviate the neck and shoulder muscle fatigue as VR sufficiently provides a more immersive and engaging experience than AR.[17] In the above mentioned study, neck fatigue was induced i.e. the asymptomatic participants were asked to use their mobile phones for 30 minutes in a neck flexed posture and the fatigue induced due to their phone use in faulty posture was relieved by using VR gaming. In our study, VR intervention was given at a time when neck muscle fatigue set in naturally while the dentists performed their routine dental tasks at their own work station, and our results indicate a significant reduction in fatigue post $VR_{intervention}$ (Figure 7, Table 4 and Table 5).

Effect of VR intervention on pain pressure threshold

PPT testing is a valuable assessment and prognostic indicator for people with neck pain. Testing the PPT at the upper trapezius site had high reliability and was clinically relevant in neck pain, as even very small changes could be detected at this site.[31]

We included dentists with a mean baseline pain pressure threshold (PPT) of 3.0 for the right upper trapezius muscle and 3.5 for the left upper trapezius muscle. In our study, the PPT was measured using a handheld algometer. Post VR intervention our study participants reported an immediate increase in the PPT by 0.75 for the right and 0.89 for the left upper trapezius muscle (Figures 7 and 8). Martínez-Segura et al reported the MDC of pain pressure threshold for the upper trapezius muscle to be between 0.45-1.13 kgf.[32] The results of our study surpassed the MDC value of pain pressure threshold which indicated that a clinically significant detectable difference was obtained in pain pressure threshold using VR intervention on both the right and left upper trapezius muscle of the participants in our study.

The PPT is frequently used for measuring pain related to a pressure stimulus.[33] Zakir Uddin et al explained how the pain pressure threshold (PPT) measure could be used to measure the pressure (mechanical) pain sensitivity (PPS). It was a reliable quantitative sensory testing (QST) technique for the assessment of pressure (mechanical) pain sensitivity of deep somatic structures in the neck area like in the upper trapezius muscle.[34] Hven in her study defined a decrease in pain threshold as an increase in pressure pain sensitivity.[35]

The results of our study indicated a statistically and clinically significant increase in the pain pressure threshold or decrease in the pain sensitivity after the VR intervention. During our literature review, we did not find any studies who used VR intervention to improve the PPT or decrease the pain sensitivity. We discovered that prior research had demonstrated that a reduction in shoulder pain led to a reduction in pain sensitivity as measured by the PPT following cervical and thoracic manipulations.[36] Another study which featured therapy with local and non-local rolling massage found a similar decrease in pain sensitivity as a result of a decrease in pain.[37] Chronic low back pain patients have also been studied, and researchers have observed lesser pain pressure threshold scores in this population. As a result, we can see that pain had an impact on these individuals' pain pressure thresholds.[38,39] Hence, we postulate that reduction in pain following VR intervention could have caused a reduction in pain sensitivity as assessed by the PPT of the upper trapezius muscle of the participants.

Central sensitization can explain many of the temporal, spatial, and threshold variations in pain sensibility in acute and chronic clinical pain settings, highlighting the basic importance of changes in the CNS to the formation of abnormal pain sensitivity. An additional phenomenon that further enhances this protective function is the sensitization of the nociceptive system that occurs after repeated noxious stimuli, so that the threshold for its activation falls and responses to subsequent inputs are amplified. In the absence of ongoing tissue injury, this increased sensitivity gradually returns to the normal baseline, requiring high-intensity stimuli to elicit nociceptive pain, the phenomenon is long lasting but not permanent.[40] Another reason for the increase in PPT post VR intervention could be the ability of VR to change cognitions related with pain adjustment. VR intervention has been effective in reducing acute pain by distracting participants' limited attention away from the source of discomfort by using its immersive environment. A study conducted by Gutierrez-Maldonado explored the changes produced by VR on cognitive variables such as pain catastrophizing and pain self-efficacy and its effect on pain-related measures such as pain threshold and pain tolerance. He found a positive effect of VR intervention on pain cognitions such as a decrease in pain catastrophizing and an increase in self-efficacy. These findings suggested that VR led participants to modify their pain cognitions to endure pain differently, which in turn produced a positive change on pain-related measures such as pain threshold andsensitivity.[41]

One of the limitations of our study was that it did not accommodate for the placebo effect in our study design. There was no control group, i.e. there was no participant in this study who did not receive the experimental treatment. This was owing to the quasi-experimental design of our study, wherein our experimental group consisted of participants on whom the effects of VR intervention were studied upon chosen via convenience sampling who fit the inclusion criteria. Since only the immediate effect was to be observed, our study focused solely on the effect of the VR intervention without adding any other intervention or without comparing it to any other treatment. This study did not use an EMG device to evaluate fatigue. This was due to the feasibility concerns with the EMG, since the study was conducted at the participant's workstation, with evaluation and treatment taking place immediately after the participant reported the onset of pain or fatigue.

Future scope of the study

Because the effect of placebo wasn't taken into account in our study design, we did not use a control group. Future studies can utilize the randomized control trial (RCT) study design to determine the effect of VR on task-related neck pain by negating the placebo effect. In our study, the effect of VR was studied on task related neck pain, fatigue and pain pressure threshold in dentists with task specific neck pain or fatigue. Future studies can focus on dentists with task related neck pain and fatigue as well as acute and chronic neck pain patients to investigate the impact of VR intervention on numerous parameters such as mood changes, kinesiophobia, and so on. In our study, only the immediate effect of a single VR intervention was assessed and no evaluation was done on subsequent days to check for the long-term effects of the intervention. Future studies can focus on the long-term effects of VR in task related, acute or chronic neck pain

CONCLUSION

Virtual reality intervention led to an immediate reduction in task-related neck pain and muscle fatigue among dentists aged 22 to 37 years. VR intervention also caused an immediate reduction in pain sensitivity as evaluated through an immediate increase of the pain pressure threshold of the upper trapezius muscle in dentists.

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