Prevalence of Upper Crossed Syndrome in Young Adults: A Cross-Sectional Study

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Abstract: ***Upper crossed syndrome is defined as a common postural dysfunctional pattern characterized by tight upper trapezius, levator scapulae on the dorsal side that crosses with tight pectoralis major and pectoralis minor paired with weak deep neck flexors ventrally thatcrosses with the middle and lower trapezius dorsally. This postural imbalance among young individuals can lead to neck pain in future. Hence, the aim of this study was to find out the prevalence of upper crossed syndrome in young males and females within the age group of 17 to 26 years. Strength of deep neck flexors and middle trapezius; length of upper trapezius and pectoralis minor were measured in 205 healthy volunteers (115 male, 90 female). SPSS version 25 software was used for data analysis and the results suggested that there is no prevalence of upper crossed syndrome in young individuals because shortness of upper trapezius was not identified. Among 205 volunteers, 55.6% had weakness of deep neck flexors, 91.22% had weakness in right middle trapezius, 96.5% had weakness in left middle trapezius, 97.07% had right pectoralis minor tightness and 89.75% had left pectoralis minor tightness. Prevalence of upper crossed syndrome was not identified among young individuals within the age group of 17 to 26 years.***

Keywords: Upper crossed syndrome, Deep neck flexors, Upper trapezius, Middle trapezius, Pectoralis minor.

1. Introduction

Upper crossed syndrome (UCS) is defined as a common postural dysfunctional pattern characterized by tight upper trapezius, levator scapulae on the dorsal side that crosses with tight pectoralis major and pectoralis minor paired with weak deep cervical flexors ventrally that crosses with the middle and lower trapezius.[1] Prevalence studies stated that among all musculoskeletal pain syndromes, neck pain was the most prevalent affecting 17.2% of adolescents due to assuming prolonged slouch posture while using a computer, smartphone, and during academic activities.[2,3] Common risk factors for postural dysfunctions are lack of knowledge of correct posture, sedentary lifestyle, occupational demands, joint stiffness, decreased fitness, muscle weakness, poor core stability, and poor ergonomic workstations. Bad posture, if not corrected, results in depression, stress, issues with digestion, poor breathing, back pain and tension headaches. Poor posture can impede the ability of the lungs to expand.[4]
The biomechanical cause of muscle imbalance resulting from repetitive movement and sustained posture which can alter the movement pattern. Due to faulty movement patterns, the joint develops a direction susceptibility to movement in a specific direction. The direction susceptibility to movement becomes the cause of pain because of microtrauma caused by stress or movement in a specific direction. A deviation of the path of the instantaneous center of rotation from the kinesiological standard is the result of impairment in the movement system.[1]

The neurological approach to muscle imbalance recognizes that muscles are predisposed to become imbalanced because of their role in motor function. The neural control unit may alter the muscle recruitment strategy to stabilize joints temporarily in dysfunction. This change in recruitment alters muscle balance, movement patterns, and ultimately the motor program. Janda considered muscle imbalance to be an impaired relationship between muscles prone to tightness or shortness and muscles prone to inhibition. More specifically, he noted that predominantly static or postural muscles tend to develop tightness. In various movements, they are activated more than the muscles that are predominantly dynamic and phasic in function, which tend to grow weak. [1,5]

Specific postural changes are associated with upper crossed syndrome including increased cervical lordosis, protracted shoulder, thoracic kyphosis, and forward head posture. This postural alteration can put unnecessary stress on the cervical spine and hence leads to early degenerative change and this may lead to neck pain.[6]

Upper crossed syndrome can be diagnosed by postural analysis, checking the strength of (middle trapezius, rhomboids, lower trapezius and deep neck flexor muscle) and by checking the length of (upper trapezius, levator scapulae, pectoralis major and pectoralis minor)[1].

Due to COVID 19 pandemic, there was an increased usage of smartphones and laptops for academic as well as official purposes. While using smartphones and laptops people tend to accommodate bad postures which may eventually lead to development of upper crossed syndrome and neck pain.

Neck pain is a universal problem and upper crossed syndrome is one of the threatening combinations of biomechanical muscle imbalance due to excessive stress it places on the structure of the upper back. People with such postural imbalance frequently complain of neck pain and if it is left unchecked, this postural imbalance can generate a chronic pain condition of the upper back and deformities like kyphosis that is more difficult to correct in later stage. Understanding neck pain and associated functional changes at younger ages might help define more appropriate intervention strategies for this age group while simultaneously contributing to the understanding of neck pain at older ages and raising awareness for the need for early interventions.

There is scarcity of literatures which shows the prevalence of upper crossed syndrome in young adults (male and females). Hence this study was designed to identify the population at risk of developing upper crossed syndrome which in long term may develop neck pain (NP) and an appropriate cost-effective corrective measure of the musculatures can be taken at an early stage which will serve to be a primary prevention strategy in preventing the risk of NP.

The purpose of this study was to find out the prevalence of upper crossed syndrome in young males and females with the age group of 17 years to 26 years.

2. Methodology

2.1 Study Design

Approval of Institute Ethical Committee (IEC) was obtained before commencement of the study. Convenient sampling was done to include 205 healthy male and female volunteers within the age group of 17 to 26 years between October 2020 to September 2021. Informed consent form (which also includes permission to use their data and photograph for presentation and publication purposes) was obtained from volunteers.

2.2 Participants

The volunteers who had a history of spinal trauma, joint dysfunction, deformity of the spine, congenital defects of the spine and upper limb, Acute spasm of paracervical muscles, sprain of any para vertebral structure like ligaments or fascia, fibromyalgia, vertigo, dizziness, spinal surgery, inflammatory disease, rheumatological condition, malignancy and any type of neurological condition were excluded from this study.

Total 223 volunteers within the age range of 17 to 26 years were approached for this study out of which 205 volunteers fulfilled the inclusion criteria.

Demographic data (age, gender, height, weight, and BMI) were gathered from each volunteer. Prior to evaluation of muscle length and strength, all the volunteers performed warm-up exercises under therapist's supervision which included neck active movements, shoulder active movements (I set of 10 repetitions with 1-minute rest), and spinal extension exercises (15 repetitions)[7].

2.3 Study tools

The strength of DNF was measured by a pressure biofeedback unit, the strength of the middle trapezius was measured using a hand-held dynamometer (HHD), length of the pectoralis minor was measured by using a set-square and the length of the upper trapezius was measured by using an inch tape. Three measurements were taken for all procedures and the mean of these measurements were considered for analysis.

2.4 Outcome Measures:

All participants were evaluated using the tests outlined below.

Measurement of deep neck flexors strength:
The craniocervical flexion (CCF) test was performed to assess the strength of the deep neck flexors. The volunteer was in hook- lying position and the head was in a neutral position. The therapist was in a standing position on the side of the assessment bed. An inflatable biofeedback pressure cuff was placed under the cervical spine, the pressure cuff dial turned towards the volunteer. The volunteer was instructed to gently nod the head to a target of 22 mmHg on the cuff and to hold the dial steady for 10 seconds. After a rest period, the same procedure was performed maintaining the target pressure at 24, 26, 28, and 30 mmHg and each time the volunteer maintained the target pressure for 10 seconds.[7,8] The muscle is considered as weak if the volunteer could not hold 28 or 30 mmHg pressure for 10 seconds.

Measurement of middle trapezius strength:
The volunteer was asked to lie on the bed in a prone lying position with glenohumeral abduction to 90 degrees and elbow flexed to 90 degrees. The therapist was in walk standing position on the tested side, therapist's one hand provided fixation by placing the hand on the opposite scapular area to prevent trunk rotation. The HHD is placed on the midline of the scapula, between the acromion process and the spinal root. The volunteer was instructed to "squeeze the shoulder blades together" to retract his or her scapula and were asked to maintain the maximum voluntary effort for 5 seconds. The therapist applied a resistance laterally through the dynamometer by matching the force exerted by the volunteer and the peak was force recorded. [38] Force less than 7 kg is considered weak.[9,10]

Measurement of pectoralis minor length:
The volunteer was in a supine lying position and adopted their natural relaxed posture with arms by their sides while the elbows were in flexed position and resting against the lateral wall of the abdomen. The therapist stood on the

side of the shoulder being tested, facing the volunteer. Without exerting any downward pressure into the table, the base of the protractor was placed on the treatment table and the vertical side was placed adjacent to the lateral aspect of the acromion. The linear distance between the treatment tables to the posterior acromion process was measured by the therapist in centimetre by using a set-square. Pectoralis minor length test distance of equal to or greater than 2.6 cm was considered as positive .[11]

Measurement of upper-trapezius muscle length:

The volunteer was in supine lying position with hip and knees bent. The therapist was in standing position and flexed the patient's head approximately 30°, laterally flexed the head away from tested side and finally rotated the head towards the tested side, while maintaining the volunteer's head in stabilized position, the therapist depressed the shoulderuntil feels the tissue stretch end feelby applying a caudal pressure on the acromion and clavicle. The length of the upper trapezius was recorded by measuring the distance between the tip of the mastoid process and acromio-clavicular joint when the upper trapezius muscle is fully lengthened. Upper trapezius length was measured and recorded by another therapist with same academic qualification. The length of $\leq$ 14.9 cm was considered as shortened.[12,13]

3. Statistical Analysis

SPSS (Statistical Package for the Social Sciences) version 25 software was used for analysis of gathered data. Descriptive statistics were used to find out the frequency of upper trapezius and pectoralis minor tightness; deep neck flexor and middle trapezius strength and finally to determine the frequency of upper crossed syndrome in male and female volunteers.

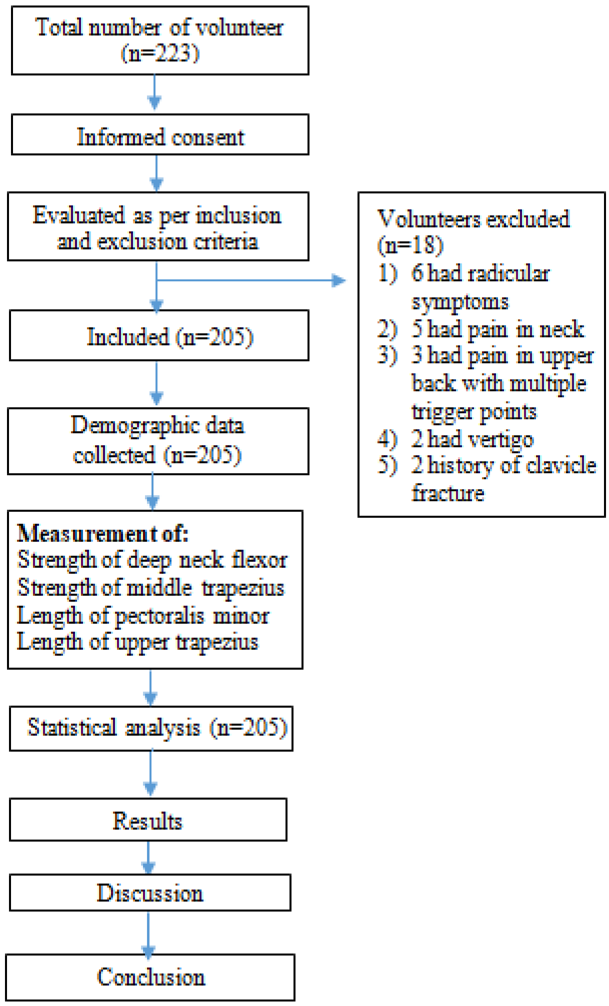

Figure 1: Consort flow Diagram

4. Results

Prevalence of upper crossed syndrome among young individuals was checked from 205 volunteers between the age group pf 17 to 26 years (Mean ± SD - 22.77 ± 4.15). Among them, 115 (56.1%) were male (Mean age ±SD - 22.97 ± 2.14) and 90 (43.9%) were females (Mean age ±SD - 22.52 ± 2.14). Mean value with standard deviation of strength of DNF, strength of middle trapezius (MT), length of pectoralis minor (PM) and upper trapezius (UT) was given in (Table 1)

Table 1: Mean values with SD of Strength of DNF, MT, and Length of PM and UT

Variables		Total (n=205)	Male (n=115)	Female (n=90)
Mean age with SD (years)		22.77± 4.15	22.52± 2.14	22.97± 2.14
Strength of DNF (mmHg)		26.88 ±2.60	27.39 ± 2.71	26.24 ± 2.30
Strength of MT (kg)	Rt	4.78 ±1.85	5.35 ± 2.14	4.0 ± 0.99
	Lt	4.12 ±1.55	4.50 ± 1.82	3.63 ± 0.89
Length of PM (cm)	Rt	4.54 ±1.15	4.71 ± 1.12	4.31 ± 1.14
	Lt	3.76 ±1.0	3.93 ± 1.08	3.53 ± 0.83
Length of UT (cm)	Rt	19.79 ±2.44	20.79 ± 2.31	20.58 ± 2.56
	Lt	19.53 ±2.61	20.58 ± 2.56	18.19 ± 2.0

Prevalence of Strength of DNF, MT and length of PM, UT among male and female individuals were given in (Table-4). Volunteers having DNF strength can't hold 28 mmHg for 10 sec. was considered weak and volunteers who had MT strength below 7 kg were considered weak. PM length test distance of equal to or less than 2.6 cm was considered as negative. Volunteers who had UT length less than 14.06 cm were considered tight. (Table-2)

Table 2: Prevalence of weakness of DNF, MT and tightness of PM, UT

Total no. of volunteers (n=205)					
		Male volunteers (n=115)		Female volunteers (n=90)	
		Number of volunteers having normal muscle strength/ length	Number of volunteers having weak muscle strength/ short muscle length	Number of volunteers having normal muscle strength/ length	Number of volunteers having weak muscle strength/ short muscle length
DNF muscle strength		64 (55.6%)	51 (44.4%)	27 (30%)	63 (70%)
MT muscle strength	Rt	17 (14.78%)	98 (85.22%)	1 (1.1%)	89 (98.9%)
	Lt	7 (6.09%)	108 (93.91%)	0 (0%)	90 (100%)
PM muscle length	Rt	2 (1.7%)	113 (98.3%)	4 (4.4%)	86 (95.6%)
	Lt	11 (9.5%)	104 (90.5%)	10 (11.1%)	80 (88.9%)
UT muscle length	Rt	114 (99.14%)	1 (0.86%)	89 (98.88%)	1 (1.2%)
	Lt	115 (100%)	0 (0%)	89 (98.88%)	1 (1.2%)

5. Discussion

Data analysis revealed that 114 (55.6%) volunteers had weakness of deep neck flexor (DNF) muscle. From 90 female volunteers 63 (70%) and among 115 male volunteers 51 (44.4%) had weak DNF muscles.

The cervical flexors, primarily the DNF (longus capitis, longus colli, rectus capitis anterior and lateralis) are postulated to assist in stabilizing the cervical spine during gross neck movements.

The possible reason for weakness of DNF may be that during COVID-19 pandemic there was an increased number of hours for mobile and laptop use for academic purposes. Flexing the neck is the most usual and regular posture adopted by mobile phone users and flexing the head forward at varying degrees can affect the spine.[14] When the head tilts forward at 15 degrees, the forces on the neck surge to 27 pounds, at 30 degrees 40 pounds and at 60 degrees 60 pounds.[15] Continuous use of smartphones can cause repetitive microtrauma to the musculoskeletal structures, this repetitive microtrauma is caused by alteration of length-tension relationship in the neck muscles and eventually, this may lead to altering DNF strength. [16] This finding is supported by Adel Alshahrani et al and Kim et al. [17,18]

Volunteers**s**who had to acquire poor sitting posture for a prolonged period while studying or using the computer may also prone to develop forward head posture which might have developed chronic muscle spasm and hence might had led to DNF weakness.[6]

From 205 volunteers 18 had strength greater than 7.00 kg and the rest 187 volunteers had strength less than 7kg in their Right Middle Trapezius (Rt MT)and 198 volunteers had Left Middle Trapezius (Lt MT) weakness. Among 90 female volunteers 89 (98.9%)and 90 (100%) had Rt and Lt MT weakness respectively. From 115 male volunteers 98 (85.22%) and 108 (93.91%) had weak Rt and Lt MT weakness respectively. These findings suggested that there was a high prevalence of MT weakness in college-going students. In this study mostly students were included and they are more likely to acquire poor posture while reading or using computers.

The possible reason may be due to prolonged slouched posture, it alters the position of the scapula and eventually, it leads to lengthening of MT and Rhomboids. Due to alteration of length-tension relationship of scapular muscles, it leads tolow static contraction during work which may resulted in abnormal recruitment of motor program, in which only type I muscle fibres are used, and this may lead to selective motor unit fatigue and damage. Eventually it leads to MT and Rhomboids weakness. [17]

The prevalence studies among healthy individuals also stated that who are using 3-4 hours with a computer and spend a valuable time in reading by acquiring a poor posture may complains neck with upper thoracic pain. Non-neutral postures of the shoulder (i.e. flexion and abduction) are also associated with musculoskeletal symptoms of the neck and upper limbs as mentioned in previous studies. [18,19]

After analysing the data, it was found that prevalence of DNF and MT weakness among female are more than male.

Helewa A et al. (1999) have stated clear difference in skeletal muscle and type of muscle fibre in males and females. They stated that male had significant greater muscle mass and lower body fat as compared to the females. Incidence of muscle weakness in female was higher than male. They also stated that slow twitch muscle fibres are predominant in female where first twitch muscle fibres are predominant in male. This is one of the reasons that muscle strength is found more in males than females in same age group. [20]

In this study, the mean value of Pectoralis Minor (PM) length was 4.54 ± 1.15 cm. Among 205 volunteers 6 had Right pectoralis minor (Rt PM) length less than 2.6 cm. and rest 199 had Right pectoralis minor length greater than 2.6 cm. and 184 volunteers had Left pectoralis minor (Lt PM) tightness. From 90 female volunteer 86 (95.6%) and 80 (88.9%) had Rt and Lt PM tightness respectively. Among 115 male volunteers 113 (98.3%) and 104 (90.5%) had Rt and Lt PM tightness respectively and rest female and male volunteers had normal PM length.

The possible mechanism might be acquiring poor or slouch posture for prolong period. Acquiring poor sitting postures for a prolonged period leads to alteration of length tension relationship in scapular muscles. [21] The force or tension that a muscle exerts varies with the length. Maximal tension is produced when the muscle fiber is approximately at a slack, or resting length because the actin and myosin filament overlap along their entire length and the number of cross bridges is maximal. In forward head posture the deep cervical flexor muscles. Rhomboids, middle and lower trapezius muscles are lengthened. There are fewer junctions between the filaments, thus the active tension decreases. Inforward head posture, deep cervical extensors (longissimus capitis, splenius capitis, cervical multifidus), shoulder protractor and elevators (PM and Levator scapulae) are shortened. Thus, there is shortening of sarcomere less than resting length which decreases the active tension. It allows overlapping of thin filaments at opposite end of sarcomere, which are functionally polarised in opposite directions. This may be one of the reasons of pectoralis minor tightness. [16]

Further, repetitive use of the upper extremity for activities that leads to protraction and downwardly rotate the scapula, which may contribute to adaptive shortening of the PM. [21]

Another possible explanation for PMtightness was given by Janda, he stated that there are three important factors in muscle tightness (Janda 1993) which are muscle length, irritability threshold and altered recruitment. A muscle that is tight usually are shorter than normal and display an altered length-tension relationship. [1] Muscle tightness leads to lowered activation threshold or lowered irritability threshold, which means that the muscle is readily activated with movement (Janda 1993). Movement typically takes the path of least resistance and so tight and facilitated muscles often are first to be recruited in the movement pattern. Tight muscle typically maintains their strength, but in extreme cases they can develop weakness.[5] In this study, the result suggests that there was a high prevalence of pectoralis minor tightness. The same finding was seen ina study by Patel C et al.[21]

In this study the mean value of length of the upper trapezius (UT) was 19.79 ± 2.44 cm. Among 205 individuals 2 (0.97%) volunteers had right upper trapezius (Rt UT) length less than 14.6 cm and rest 203 (99%) volunteers had Rt UTlength greater than 14.6 cm. and 1 volunteer had left upper trapezius (Lt UT) tightness. Their findings suggested that there was no compromised length seen in the UT in college-going students.

From 90 female volunteers 1(1.2%) and 1(1.2%) had Rt and Lt UT tightness respectively. Among 115 male volunteers 1 (0.86%) had Rt UT tight ness and no one had Lt UT tightness.

The pieces of literature regarding the prevalence of UT tightness suggested that the individuals having overuse shoulder syndrome had a significant reduction in UT length and also the persons who had neck pain also had a significant reduction in UT length along with increased craniocervical angle and thoracic curvature. There is a lack of evidence regarding which shows shortened UT length in healthy individuals, but some literature suggested that the compromised UT length is uncommon unless there were trigger points and neck pain.[22,23]. In this study volunteers having multiple trigger points, shoulder pain, neck and upper back pain were excluded. This may be one reason for which UT tightness was not found in this study.

6. Conclusion

Prevalence of UCS in young individuals could not be established because shortness of upper trapezius muscle was not identified in this study. However, this study showed that there is higher prevalence of tightness of pectoralis minor, weakness of middle trapezius and weakness of DNF among young individuals.

7. Limitations and Future Recommendations

In this study forward head posture and tightness of levator scapulae was not assessed. Upper trapezius length could have been measured using active movements. Age specific stratification of the data can be recommended for the future studies to get a more appropriate prevalence of UCS in Indian populations. Demographic data (height, weight, age, gender, BMI) can be used for finding out the correlation between the variables for future analysis. Corelation between UCS and neck pain can be established in future studies.

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Conflict of interest

The authors declare that there is no conflict of interest.

References

[1] Page P, Frank C, Lardner R. Assessment and treatment of muscle imbalance: The Janda approach: Canada: Human kinetics. 2010.

[2] Smith L, Louw Q, Crous L, Grimmer-Somers K. Prevalence of neck pain and headaches: impact of computer use and other associative factors. Cephalalgia. 2009;29(2):250-7.

[3] Talwar R, Kapoor R, Puri K, Bansal K, Singh S. A study of visual and musculoskeletal health disorders among computer professionals in NCR Delhi. Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine. 2009;34(4):326.

[4] Szeto G, Straker L, O'Sullivan P. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work: Neck and shoulder muscle recruitment patterns. Manual Therapy. 2005; 10(4): 270-280.

[5] Sherrington C S. On reciprocal innervation of antagonistic muscles. Tenth note. Proceedings of the Royal Society of London Series B, Containing Papers of a biological character. 1907; 79(532): 337-349.

[6] Dhage P, Anap D. Prevalence of an " upper crossed syndrome in physiotherapy college student "- A cross-sectional study. VIMS Health science journal. 2019; 6(1): 10-13.

[7] Krisner C, Colby A, Therapeutic exercise foundation and techniques 5th edition, FA davis company, Philadelphia. 2007.

[8] Wing Chiu TT, Hung Law EY, Fai Chiu TH. Performance of the craniocervical flexion test in subjects with and without chronic neck pain. Journal of Orthopaedic & Sports Physical Therapy. 2005;35(9):567-71.

[9] Turner N, Ferguson K, Mobley B, Riemann B, Davies G. Establishing normative data on scapulothoracic musculature using handheld dynamometry. Journal of sport rehabilitation. 2009;18: 502-520.

[10] Senthil P, Radhakrishnan R.Normative data and intra - rater reliability of scapula - humeral muscle strength using push - pull hydraulic type hand held dynamometer in healthy college students. International journal of health sciences and research. 2016; 6(6): 177-181.

[11] Lewis J, Valentine R. The pectoralis minor length test: a study of the intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms. BMC musculoskeletal disorders. 2007; 8(1): 1-10.

[12] Edgar D, Jull G, Sutton S. The relationship between upper trapezius muscle length and upper quadrant neural tissue extensibility. Australian Journal of Physiotherapy. 1994; 40(2): 99-103.

[13] Norkin C, White J. Measurement of joint motion: A guide to goniometry. 3rd Ed. New Delhi, India. Jaypee. 2004: 21-25.

[14] Berolo S, Wells RP, AMICK BC. Musculoskeletal symptoms among mobile hand-held device users and their relationship to device use: a preliminary study in a Canadian university populations. Applied ergonomics. 2011;42(2):371-8.

[15] Hansraj KK. Assessment of stress in the cervical spine caused by posture and position of the head. Surgical technology international. 2014;25(25):277-9.

[16] Nordin M, Frankel V H. Basic Biomechanics of the musculoskeletal system; 4th edition. Lippicott Williams & Wilkins: Wolter Kluver; 2012.

[17] Alshahrani A, SamyAbdrabo M, Aly SM, Alshahrani MS, Alqhtani RS, Asiri F, Ahmad I. Effect of Smartphone Usage on Neck Muscle Endurance, Hand Grip and Pinch Strength among Healthy College Students: A Cross-Sectional Study. International Journal of Environmental Research and Public Health. 2021 Jan;18(12):6290.

[18] Bisht D, Bakhshi R. Knowledge of computer ergonomics and incidence of musculoskeletal disorders among students of Punjab Agricultural University, Ludhiana, India. Journal of Applied and Natural Science. 2018;10(1):323-9.

[19] Larsson B, Bjo¨rk J, Henriksson KG, et al. The prevalences of cytochrome c oxidase negative and superpositive fibres and ragged-red fibres in the trapezius muscle of female cleaners with and without myalgia and of female healthy controls. Pain 2000;84:379–387.

[20] Helewa AN, Goldsmith CH, Lee P, Smythe HA, Forwell LO. Does strengthening the abdominal muscles prevent low back pain--a randomized controlled trial. The Journal of rheumatology. 1999;26(8):1808-15.

[21] Patel C, Patel S. Presence of Pectoralis Minor Tightness in Healthy Collegiate Individuals. JOSPT. 2020 Jan;14(1):219.

[22] Hägg GM, Åström A. Load pattern and pressure pain threshold in the upper trapezius muscle and psychosocial factors in medical secretaries with and without shoulder/neck disorders. International archives of occupational and environmental health. 1997;69(6):423-32.

[23] Greenfield B, Catlin PA, Coats PW, Green E, McDonald JJ, North C. Posture in patients with shoulder overuse injuries and healthy individuals. Journal of Orthopaedic & Sports Physical Therapy. 1995;21(5):287-95.