Screening on Collect Students: Postural Risk Factors of Spinal Musculoskeletal Problems and Scoliosis

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Research Article

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Abstract

Background: Overuse of electronic products and decrease in levels of physical activity may lead to an increased incidence of spinal health problems in college students. This study aims to 1) identify the incidence of spinal health problems in college students, 2) to explore the key postural factors in development of spinal musculoskeletal dysfunction and scoliosis, and 3) to clarify new strategies for early identification and prevention of scoliosis.

Methods: A cross-sectional screening by static posture assessment, selective functional movement assessment (SFMA) and Adam's Forward Bend Test, was conducted to 306 college students from October to December 2019. Descriptive analysis, Spearman correlation analysis and binomial logistic regression analysis were performed on the collected data.

Results: Static postural assessment was completed among 306 college students, 53% of students' external auditory meatus and acromioclavicular joint were not in the same gravitational line, 45% had forward-head posture, 42% had uneven shoulders. When performing SFMA, we found spinal musculoskeletal dysfunctions, including abnormalities of multi-segment spine flexion (32%), cervical rotation to right (18%), cervical rotation to left (16%), etc. In Adam's Forward Bend Test, 10.78% had a positive result, which suggested structural or functional scoliosis. Correlation analysis showed that the top three postural factors related to spinal musculoskeletal dysfunctions included uneven shoulders, forward-head, position of thorax and pelvis rotated. And top three postural factors related to scoliosis were spinous processes line deviating from midline, winged scapula and head rotation off midline. Logistic regression analysis displayed that there are two high risk factors for scoliosis, including external auditory meatus and acromioclavicular joint not in the same vertical line (OR = 6.314), and deviation of spinous processes line (OR = 12.743).

Conclusions: Poor posture, spinal musculoskeletal dysfunction and scoliosis affect a significant proportion of college students. While their spinal musculoskeletal dysfunction and scoliosis are closely related to poor posture.

1 Background

Wireless network has been available in wide areas in this world [1]. As an important tool for education, most educational institutes in China provide network services to students [2]. At the meantime, increase numbers of students have smart phones or personal digital devices [3].

Overuse of smart phone or personal digital device will induce decreasing of physical or outdoor activities [4]. Reading message from electronic products required students maintain their posture in an unnatural way, such as sitting with round back, forward head, or crossed legs (one leg on top of the other) for a long period of time. The lack of movement and prolonged unnatural position contribute to the increased occurrence of poor posture and spinal deformities [5]. College students are among the worst group of users in reading messages from smart phones or personal digital devices for longer time with poor posture [6, 7].

It was reported that prolonged time in poor posture is associated with asymmetric load [8] and further deteriorates muscular balance [9, 10]. While spinal muscular unbalance for a long period of time may cause a visible curvature in the spine, which can be reversible in most of cases by rehabilitation therapy [11]. If the curvature is not detected and corrected at this phase, the unbalanced force loading on to the spine will cause deformation of the spine and may eventually cause structural scoliosis. In patients with structural scoliosis, the spinous processes tend to be concave and varying degrees of rotation may also occur in the ribs and joints [12]. In other words, prolonged time in keeping

the body in a poor posture will induce paravertebral muscle pain, unbalanced force application to the vertebral bone, and even worse, permanent spinal malformation, including scoliosis.

To prevent developmental spine problems in adolescence, many educators promoted physical activity in schools [13]; they developed guideline for restricting hours of smart phone usage [14]. Healthcare staff carried out screens on students with a goal to identify reversible spinal curves and give them appropriate treatments in the early phase [15]. However, few previous reports examined the causal relationship between poor posture and the occurrence of spinal musculoskeletal damages even scoliosis. What’s more, we do not know key risk factors caused by poor postures that contribute to the development of scoliosis.

We aimed to find answers to these questions, specifically, through a cross-sectional screening by static posture assessment, selective functional movement assessment (SFMA) and Adam's Forward Bend Test, we tried to clarify the epidemiology of body posture, spinal musculoskeletal dysfunction and scoliosis in college students, then to explore posture-related factors in development of musculoskeletal damage and scoliosis to provide key indicators for monitoring and prevention strategies, and look for treatment strategies for college students' spinal damages through therapeutic guidance of SFMA.

2 Methods

2.1 Ethic statement

Methods used in the study were reviewed and approved by the Ethics Board of the Second Hospital of Jilin University (No 2020-019). Informed consent was signed before participating in screening.

2.2 Screening for spinal health problem of college students

2.2.1 Participants

It was a cross-sectional screening study carried over 3 months’ period using convenient sampling technique from October till December 2019 by the Department of Rehabilitation Medicine, Second Hospital of Jilin University. Students were freshmen selected by random selection of 9 colleges in Jilin University, a comprehensive university in China, whose students came from all over the country, which can represent the data distribution of Chinese college students.

2.2.2 Screening method

In this study, we used the static posture assessment to determine the abnormality of body posture, used selective functional movement assessment (SFMA) to identify relevant musculoskeletal dysfunction [16] and to assist the diagnosis and treatment of skeletal muscle diseases [17]. And Adam's Forward Bend Test was applied on the screening for scoliosis [18]. Assessment form was attached in the appendix.

Static postural assessment Postural assessment entailed observation of static posture for alignment and visual and palpable assessment of paired anatomic landmarks for symmetry. The patient was instructed to stand still, with feet shoulder-width apart, face forward, and arms relaxed to the sides. The patient's posture should be evaluated from anterior, lateral, and posterior views. The examiner should observe and palpate where appropriate in all views and levels. Lateral symmetry of posture was evaluated by imagining a line drawn from the ceiling to the floor through the midline of the patient's body. Ideally, this line passed through the following points: the external auditory meatus, the acromioclavicular joint, the greater trochanter, and a point just anterior to the lateral malleolus. Observation of

postural misalignment or asymmetries may indicate problems such as scoliosis, postural decompensation, or specific segmental somatic dysfunctions in the body regions where asymmetry was observed.

Selective Functional Movement Assessment (SFMA) The SFMA was broken down into 7 Top Tier (ie, basic movement) tests including Cervical Patterns (flexion, extension), Cervical Patterns (rotation R+L), Upper-Extremity Patterns, Multi-segmental flexion, Multi-segmental extension, Multi-segmental rotation (R + L), single-leg stance (R + L) and overhead squat. And the SFMA was graded as Functional non-painful (FN), Functional painful (FP), Dysfunctional non-painful (DN), and Dysfunctional painful (DP) [17]. In this study, in order to assess asymmetries and pathological movements patterns of spine, 5 Top-tier tests including Cervical Patterns (flexion, extension), Cervical Patterns (rotation R+L), Multi-segmental flexion, Multi-segmental extension and Multi-segmental rotation, were used to screen for spinal musculoskeletal dysfunction of college students.

Adam's Forward Bend Test The subjects stood with their feet as wide as shoulders, and bent forward as far as possible. Looked for the higher side of the rib cage next to the vertebral column, which was the convex side and suggested Adam's Test was positive. The subjects should be instructed to bend forward, backward, then bend sideward, rotate to the right and left. They also should repeat above Adam's Test to identify individuals with scoliosis.

2.3 Statistical analysis

All data were statistically analyzed and plotted using SPSS17.0 (IBM Corporation, Chicago, USA). Descriptive statistics was used for analyzing the percentages of spinal health problems in college students; Spearman correlation analysis was used for reveal relationship of results among three different screening methods; binomial logistic regression analysis was used to analyze the risk factors of scoliosis. $p < 0.05$ was considered as statistically significant.

3 Results

This study involved 306 college students with an average age of 18.98 ± 0.77 years, including 225 males and 81 females. Their average body mass index (BMI) was 22.21 ± 4.77.

3.1 Results of spinal health problem screening

3.1.1 Static postural assessment

In the detection of anterior view, 38% of 306 college students appeared head side bending, 29% had round shoulders, 17% students' anterior superior iliac spines (ASIS) were not in the same level, 16% appeared knee deformity including 7% varus knees and 9% valgus knees, 5% students' position of thorax and pelvis appeared rotated. In the lateral view, 53% of college students' external auditory meatus and acromioclavicular joint were not in the same gravitational line, 45% had forward-head posture, 28% appeared protruding abdomen, 14% appeared abnormal lumbar lordosis including 12% increased lordosis and 2% disappeared lordosis, 8% appeared abnormal thoracic kyphosis including 5% increased kyphosis and 3% disappeared kyphosis. In posterior view, 42% had uneven shoulders, 18% appeared uneven inferior angles of the scapulas, 14% had head rotation, 10% appeared winged scapulas, 10% had uneven posterior superior iliac spines (PSIS), 10% students' spinous processes (SP) line deviated from the midline (Table 1).

Table 1
Results of static postural assessment in college students

	Items of static postural assessment	Percentage of abnormality
Anterior view	head side bending or not	38%
	round shoulder or not	29%
	ASIS level	17%
	knee deformity or not	16%
	position of thorax and pelvis rotated or not	5%
Lateral view	external auditory meatus and acromioclavicular joint in same vertical line or not	53%
	forward-head posture or not	45%
	protruding abdomen or not	28%
	lumbar lordosis normal or not	14%
	thoracic kyphosis normal or not	8%
Posterior view	shoulders level	42%
	inferior angles of the scapula level	18%
	head rotation off midline or not	14%
	winged scapulas or not	10%
	PSIS level	10%
	SP line deviating from midline or not	10%

3.1.2 SFMA

When performing SFMA on the 306 college students, 32% suffered from abnormalities in multi-segment spine flexion test, of which 17% were normal function with pain (FP), 7% were abnormal function without pain (DN), and 8% were abnormal function with pain (DP). Other spinal musculoskeletal dysfunctions included abnormalities in cervical rotation to right (18%), cervical rotation to left (16%), multi-segment spine extension (16%), cervical extension (15%), cervical flexion (12%) and multi-segment spine rotation (10%) (Table 2).

Table 2
Results of SFMA in college students

	Functional non-painful (FN)	Functional painful (FP)	Dysfunctional non-painful (DN)	Dysfunctional painful (DP)
Cervical flexion	88%	5%	5%	2%
Cervical extension	85%	12%	2%	1%
Cervical rotation to left	84%	8%	5%	3%
Cervical rotation to right	82%	8%	7%	3%
Multi-segmental flexion	68%	17%	7%	8%
Multi-segmental extension	84%	10%	4%	2%
Multisegmental rotation to left	90%	8%	1%	1%
Multisegmental rotation to right	90%	7%	2%	1%

3.1.3 Adam's Forward Bend Test

Among 306 college students, 10.78% were asymmetrical in Adam's Forward Bend Test, of which 4.90% were convex on the left side and 5.88% were convex on the right side.

3.2 Spearman correlation analysis among three screening methods

In order to analyze the posture-related factors in development of spinal musculoskeletal dysfunction and scoliosis, we carried out Spearman correlation analysis on SFMA assessment (FN = 0, FP = 1, DN = 2, DP = 3), Adam's test (symmetry = 0, asymmetry = 1) and static posture assessment (normal = 0, abnormal = 1) separately.

3.2.1 Correlation analysis between SFMA and static postural assessment

As shown in Table 3, postural factors related to abnormality of cervical flexion included abdomen protruding (r = 0.144), knee deformity (r = 0.116) and external auditory meatus and acromioclavicular joint not in the same vertical line (r = 0.115). The top three posture relevant factors of abnormality of cervical extension were uneven shoulders (r = 0.194), changes of thoracic kyphosis (r = 0.144), and uneven inferior angles of scapulas (r = 0.119). The top three postural relevant factors of abnormality of cervical rotation to left involved uneven inferior angles of scapulas (r = 0.239), external auditory meatus and acromioclavicular joint not in the same vertical line (r = 0.226) and head rotation (r = 0.206). The top three postural relevant factors of abnormality of cervical rotation to right were changes of thoracic kyphosis (r = 0.211), uneven shoulders (r = 0.20) and external auditory meatus and acromioclavicular joint not in the same vertical line (r = 0.196). It suggested that uneven shoulders, forward-head and changes of thoracic kyphosis were main postural factors of abnormality of cervical pattern tests. Similarly, the main postural relevant factors of abnormality of muti-segment spinal pattern tests included position of thorax and pelvis rotated, forward-head, uneven shoulders, uneven hip (pelvic tilt), changes of lumbar lordosis (Table 3).

Table 3
Spearman correlation analysis between SFMA and static postural assessment

	cervical flexion	cervical extension	cervical rotation to left	cervical rotation to right	multi segment flexion	multi segment extension	multi segment rotation to left	multi segment rotation to right
Rounding shoulder or not	.045	.051	.131*	.051	-.054	-.014	.039	.039
position of thorax and pelvis rotated or not	.059	-.003	.188**	.131*	.059	.111	.223**	.133*
Knee deformity or not	.116*	.065	.183**	.121*	-.013	.062	.114*	.010
Forward head or not	.027	.056	.139*	.029	.133*	.029	.063	.012
external auditory meatus and acromioclavicular joint in same vertical line or not	.115*	.118*	.226**	.196**	.116*	.189**	.080	.109
thoracic kyphosis normal or not	.062	.144*	.101	.211**	.025	.188**	.058	.110
lumbar lordosis normal or not	.094	.066	.082	.090	.017	.166**	.114*	.124*
Abdomen protruding or not	.144*	.036	.019	-.001	.003	-.009	-.005	.041
Head rotation or not	.088	.047	.206**	.168**	.071	.166**	.142*	.132*
shoulders in same level or not	.095	.194**	.163**	.200**	.177**	.109	.057	.130*
inferior angles of scapula in same level or not	-.016	.119*	.239**	.191**	.094	.163**	.180**	.136*
winged scapula or not	.103	.049	.142*	.138*	.140*	.152**	.069	.043
PSIS in the same level or not	.104	.020	.172**	.168**	.063	.172**	.129*	.110
SP line deviating from the midline or not	-.018	-.039	.106	.089	.032	.080	.151**	.052

Note: *$p<0.05$, **$p<0.01$.

3.2.2 Correlation analysis between Adam's Test and postural assessment, SFMA

The postural factors related to scoliosis were shown in Table 4. The top three related factors were SP line deviating from midline (r = 0.319), winged scapula (r = 0.232), and head rotation off midline (r = 0.193). Besides, scoliosis also related to abnormality of SFMA including cervical rotation to left (r = 0.185), cervical rotation to right (r = 0.183), multi-segment extension of spine (r = 0.177), etc.

Table 4
Spearman correlation analysis between Adam's Test and static postural assessment, SFMA

Related assessment	correlation coefficient	*P* value
position of thorax and pelvis rotated or not	0.165	0.004
external auditory meatus and acromioclavicular joint not in the same vertical line or not	0.157	0.006
head rotation off midline or not	0.193	0.001
shoulders in the same level or not	0.132	0.021
inferior angles of scapula in the same level or not	0.114	0.047
winged scapula or not	0.232	0.000
PSIS in the same level or not	0.191	0.001
SP line deviating from midline or not	0.319	0.000
cervical flexion	0.158	0.005
cervical rotation to left	0.185	0.001
cervical rotation to right	0.183	0.001
multi-segment extension of spine	0.177	0.002
multi-segment spine rotation to left	0.152	0.008

3.3 Binomial logistic regression analysis of Adam's Forward Bend Test

To explore risk factors of posture and spinal musculoskeletal dysfunction contributing to the scoliosis, we performed a binomial logistic regression analysis, where results in Adam's Test (Y, symmetry = 0, asymmetry = 1) were predicted by gender (X_1, male = 1, female = 2), age (X_2), BMI (X_3), static posture assessment (X_4 - X_{19}, normal = 0, abnormal = 1), SFMA assessment (X_{20} - X_{27}, FN = 0, FP = 1, DN = 2, DP = 3). Results were displayed in Table 5. People who reported as external auditory meatus and acromioclavicular joint not in the same vertical line were 6.314 times more likely to have scoliosis than those whose external auditory meatus and acromioclavicular joint were in the same vertical line ($p < 0.05$). And people whose SP line deviated from the midline were 12.743 times more likely to have scoliosis than those whose SP line did not deviate from the midline ($p < 0.05$).

Table 5
Binomial logistic regression analysis of results of Adam's Test

Related factors	B	S.E.	EXP(B)	95% C.I. of EXP(B)		*p*
				lower	upper	
external auditory meatus and acromioclavicular joint not in the same vertical line or not	1.843	0.879	6.314	1.128	35.345	0.036
SP line deviating from midline or not	2.545	1.008	12.743	1.768	91.816	0.012
constant	-10.654	9.118	0.212			0.024

4 Discussion

Results in this study showed that poor posture, spinal musculoskeletal dysfunctions and scoliosis were common in college students, which could be considered as three steps of spinal health problems among them. More specifically, poor posture in college students included external auditory meatus and acromioclavicular joint not in the same gravitational line, forward-head, uneven shoulders, head side bending off midline, round shoulders, protruding abdomen, etc. Spinal musculoskeletal dysfunctions mainly involved abnormalities of multi-segment spine flexion, cervical rotation and multi-segment spine extension. Among them, incidence of scoliosis was 10.78% measured by Adam's Test. Khosrovi et al. reported a higher prevalence of 17.9% [19] among same age group in Iran. Thus, spinal health of college students is a serious problem.

By Spearman correlation analysis, we found that key postural factors related to spinal musculoskeletal dysfunction included uneven shoulders, forward-head, position of thorax and pelvis rotated, changes of thoracic kyphosis and head rotation off midline (Table 3). It’s reported that musculoskeletal pain among undergraduate students is related to overweight, not having time for leisure, six or more daily hours of mobile phone use [10]. While prolonged sitting and reduced flexibility were probably related to incidence of forward head, thoracic kyphosis, and pronated foot [20]. Casas et al. found that neck and back pain of college students is associated with sitting posture with rounded back, feet supported on another chair and crossed legs [21]. Thus, correcting cervical and thoracic postural abnormalities when long hours sitting is the key point for prevention of musculoskeletal dysfunctions.

Postural factors related to scoliosis were spinous processes line deviating from midline, winged scapula and head rotation off midline (Table 4). It’s known that trunk balance is maintained by mutual interaction of varieties of factors including visual information, lower limb kinematics, muscle strength of the trunk and limbs and so on [22]. After a long time for deviation of spinous processes line, head and cervical spine play pivotal roles in influencing global subjacent spinal alignment and pelvic tilt, as compensatory changes occur to maintain horizontal gaze [23]. And head rotation off midline maybe a way of visual compensation for trunk unbalance. Besides, Purnama et al. found winging scapula was identified in all athlete’s table tennis and tennis with scoliosis because of muscle imbalance in the kinetic link of the upper body [24]. It’s also reported that main compensatory mechanisms of scoliosis patients adopt to maintain an upright posture include decreased sacral slope, increased pelvic tilt, decreased thoracic kyphosis [25]. Once it does decompensate, three-dimensional deformation of spine will be induced or severe. Therefore, early inspection on the spinous processes line, winged scapula and head rotation, should be considered as routine interventions to effectively identify the progress of scoliosis in college students.

By binomial logistic regression analysis, external auditory meatus and acromioclavicular joint not in the same gravitational line was shown as one of the high risk factors for scoliosis in this study (Table 5). External auditory meatus and acromioclavicular joint not in the same gravitational line usually means rotation or forward displacement of the head on the cervical spine [26]. In this study, 14% of college students appeared head rotation, and 45% had forward-head posture. The latter can be considered as the main cause of external auditory meatus and acromioclavicular joint not in the same vertical line. Forward-head posture is characterized by hyperextension of the upper cervical spine and flexion of the lower cervical spine, which is associated with shortening of the upper trapezius, posterior cervical extensor muscles, sternocleidomastoid, and levator scapulae muscles [27]. With the increase of compressive forces caused by forward-head on the cervical apophyseal joints and posterior part of the vertebra and changes in connective tissue length and strength, cervical lordosis and thoracic kyphosis values will be significantly affected [28]. Maybe this is the hidden mechanism of scoliosis induced by forward head posture.

Spinous processes (SP) line deviating from the midline was suggested as another high risk factor for scoliosis. SP line is usually used as a low-cost, easy to use, radiation free method during family screening for scoliosis. It's also reported that it is important to monitor the spine trunk deviation when a person is standing straight, because it can indicate whether or not the subject has orthopathology [29]. Thus, external auditory meatus and acromioclavicular joint not in the same vertical line and deviation of SP line can be considered as important indicators for monitoring and prevention strategies of scoliosis.

Furthermore, the SFMA is a standardized movement assessment tool intended to provide a systematic process to identify the best possible therapeutic and corrective treatment program for patients. In our study, we analyzed correlation among SFMA, posture assessment and scoliosis (Table 3). Result showed that rounded-shoulder was related to limitation of active cervical rotation. Rounded-shoulder posture is characterized by a protracted, downwardly rotated, and anteriorly tipped scapula position with increased cervical lordosis and upper thoracic kyphosis [30]. Rounded-shoulder was results from loss of lower trapezius and serratus anterior activity, tightness in the pectoralis minor, which can easily cause the overuse of the upper trapezius muscle, which affects the contralateral rotation of the cervical spine. Thus, using SFMA, we can find abnormality of cervical rotation of college students with rounded-shoulders. Physical therapist can treat cervical rotation related muscles to correct the round shoulder posture. It has been proved that the posterior tilting exercise after pectoralis minor stretching is the most effective method for eliciting greater lower trapezius and serratus anterior muscle activation [31]. Due to the tight connection between scoliosis and abnormalities of cervical rotation and multi-segment spine extension (Table 4), correcting these abnormalities may help reduce the chance of scoliosis.

5 Conclusions

College students are high-risk groups with spinal health problems. Our studies have confirmed that college students' spine musculoskeletal dysfunction and scoliosis are closely related to poor posture. There are two significant risk factors for scoliosis, including external auditory meatus and acromioclavicular joint not in the same vertical line and deviation of spinous processes line. They can be applied on early recognition and prevention of scoliosis. Additionally, SFMA can be used in clinical practice to evaluate the spine musculoskeletal dysfunction, and to guide targeted treatments to correct poor posture and scoliosis.

Abbreviations

SFMA: Selective functional movement assessment

FN: Functional non-painful

FP: Functional painful

DN: Dysfunctional non-painful

DP: Dysfunctional painful

BMI: Body mass index

ASIS: Anterior superior iliac spines

PSIS: Posterior superior iliac spines

SP: Spinous processes

Declarations

Ethics approval and consent to participate

Methods used in the study were reviewed and approved by the Ethics Review Board of the Second Hospital of Jilin University (No 2020-019). Informed consent was signed before participating in screening.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

XQD contributed to the conception, design of the study. JY contributed to acquisition of the data and drafted the text. WML, TZ, JHY performed physical examination for students. ZBS contributed to data collection and analysis. BZ was a major contributor in modifying the manuscript. All authors have read and approved the final manuscript.

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References

1. Islam MS, Islam MT, Almutairi AE, Beng GK, Misran N, Amin N. Monitoring of the Human Body Signal through the Internet of Things (IoT) Based LoRa Wireless Network System. Appl Sci-Basel. 2019;9(9).
2. Y S. The Current Situation and Improvement Suggestions of Information Management and Service in Colleges and Universities—Investigation of Xianyang City, Western China. In: Liu Q, Liu X, Shen T, X. Q, editors. The 10th International Conference on Computer Engineering and Networks. 1274. Singapore: Springer; 2020. p. 635-42.
3. Brown C, G. H. Using Personal Mobile Devices to increase flexibility and equity in learning in resource constrained contexts. Journal of Open, Flexible, and Distance Learning. 2018;22(2):18–31.
4. Liew LWL, Stavropoulos V, Adams BLM, Burleigh TL, Griffiths MD. Internet Gaming Disorder: the interplay between physical activity and user-avatar relationship. Behav Inform Technol. 2018;37(6):558–74.
5. Rusnak R, Kolarova M, Astaryova I, Kutis P. Screening and Early Identification of Spinal Deformities and Posture in 311 Children: Results from 16 Districts in Slovakia. Rehabil Res Pract. 2019;2019.
6. Guo Y, Xu M, Zhang J, Hu Q, Zhou Z, Wei Z, et al. The effect of Three-Circle Post Standing (Zhanzhuang) Qigong on the physical and psychological well-being of college students: Study protocol for a randomized controlled trial. Medicine (Baltimore). 2018;97(38):e12323.
7. Dinesh Shanmugam, Subramaniyam. M. Spine curvature data measurement and its application on product development. IOP Conf Ser: Mater Sci Eng. 2020;912:022045.
8. Nagymáté G, Takács M, Kiss RM, Khaiyat O. Does bad posture affect the standing balance? Cogent Medicine. 2018;5(1):1503778.
9. Hasan MM, Yaqoob U, Ali SS, Siddiqui AA. Frequency of Musculoskeletal Pain and Associated Factors among Undergraduate Students. Case Reports in Clinical Medicine. 2018;07(02):131–45.
10. Morais BX, Dalmolin GL, Andolhe R, Dullius A, Rocha LP. Musculoskeletal pain in undergraduate health students: prevalence and associated factors. Rev Esc Enferm USP. 2019;53:e03444.
11. Jing-mei DONG, Yi YU, Tian-feng LU, Yun-he ZHOU, ZHOU. P. Intervention Research on the Medical Yoga Teaching of MTT on the Female College Student's Spin Problems——A Case Study of Tongji University. China School Physical Education (Higher Education). 2017;4(5):34–9.
12. Morrison DG, Chan A, Hill D, Parent EC, Lou EH. Correlation between Cobb angle, spinous process angle (SPA) and apical vertebrae rotation (AVR) on posteroanterior radiographs in adolescent idiopathic scoliosis (AIS). Eur Spine J. 2015;24(2):306–12.
13. Guddal MH, Stensland SO, Smastuen MC, Johnsen MB, Zwart JA, Storheim K. Physical Activity Level and Sport Participation in Relation to Musculoskeletal Pain in a Population-Based Study of Adolescents: The Young-HUNT Study. Orthop J Sports Med. 2017;5(1):2325967116685543.
14. Rather MK, SA. R. Impact of Smartphones on Young Generation. Library Philosophy and Practice (e-journal). 2019;4(10):2384.
15. Clark EM, Tobias JH, Fairbank J. The Impact of Small Spinal Curves in Adolescents Who Have Not Presented to Secondary Care: A Population-Based Cohort Study. Spine (Phila Pa 1976). 2016;41(10):E611-7.
16. Dolbeer J, Mason J, Morris J, Crowell M, D. G. Inter-rater reliability of the selective functional movement assessment (SFMA) by SFMA certified physical therapists with similar clinical and rating experience. Int J Sports Phys Ther. 2017;12(5):752–63.
17. Stanek JM, Smith J, Petrie J. Intra- and Inter-rater Reliability of the Selective Functional Movement Assessment (SFMA) in Healthy Participants. International Journal of Sports Physical Therapy. 2019;14(1):107–16.

18. Khosrovi G, Vakili Z, Sharif M R, M. S. Comparing Anthropometric Characteristics of Normal Versus Scoliotic Girl Students in Guidance School. Int J Sport Stud Hlth. 2018;1(2):e8036.
19. Khosrovi G, Vakili Z, Sharif M R, M. S. Comparing Anthropometric Characteristics of Normal Versus Scoliotic Girl Students in Guidance School. Int J Sport Stud Hlth. 2018;1(2):e80361.
20. Kiruthika S, Rekha K, G P, Abraham M. Prevalence of Postural Dysfunction among Female College Students?A Qualitative Analysis. Biology and Medicine. 2018;10(1).
21. Casas AS, Patiño MS, DM. C. Association between the sitting posture and back pain in college students. Rev Univ Ind Santander Salud. 2016;48(4):446–54.
22. Nishida M, Nagura T, Fujita N, Hosogane N, Tsuji T, Nakamura M, et al. Position of the major curve influences asymmetrical trunk kinematics during gait in adolescent idiopathic scoliosis. Gait Posture. 2017;51:142–8.
23. Tundo F, Avila MJ, Willard L, Fanous S, Curri C, Hussain I, et al. Spinal alignment, surgery, and outcomes in cervical deformity: A practical guide to aid the spine surgeon. Clin Neurol Neurosurg. 2019;185:105496.
24. Purnama MS, Doewes M, SK. P. Comparison of scoliosis posture athlete's table tennis and tennis at children and adolescents. Journal of Education, Health and Sport. 2018;8(10):149–62.
25. Cheung JPY. The importance of sagittal balance in adult scoliosis surgery. Ann Transl Med. 2020;8(2):35.
26. Ghamkhar L, Kahlaee AH. Is forward head posture relevant to cervical muscles performance and neck pain? A case-control study. Braz J Phys Ther. 2019;23(4):346–54.
27. Ruivo RM, Pezarat-Correia P, Carita AI. Effects of a Resistance and Stretching Training Program on Forward Head and Protracted Shoulder Posture in Adolescents. J Manipulative Physiol Ther. 2017;40(1):1–10.
28. Singla D, Veqar Z. Association Between Forward Head, Rounded Shoulders, and Increased Thoracic Kyphosis: A Review of the Literature. J Chiropr Med. 2017;16(3):220–9.
29. Zhenda Xu, Yong Zhang, Chunyang Fu, Limin Liu, Cong Chen, Wenchao Xu, et al. Back Shape Measurement and Three-Dimensional Reconstruction of Spinal Shape Using One Kinect Sensor. 2020 IEEE 17th International Symposium on Biomedical Imaging (ISBI); Iowa City, IA, USA2020. p. 1-5.
30. Shiravi S, Letafatkar A, Bertozzi L, Pillastrini P, Khaleghi Tazji M. Efficacy of Abdominal Control Feedback and Scapula Stabilization Exercises in Participants With Forward Head, Round Shoulder Postures and Neck Movement Impairment. Sports Health. 2019;11(3):272–9.
31. Lee JH, Cynn HS, Yoon TL, Ko CH, Choi WJ, Choi SA, et al. The effect of scapular posterior tilt exercise, pectoralis minor stretching, and shoulder brace on scapular alignment and muscles activity in subjects with round-shoulder posture. J Electromyogr Kinesiol. 2015;25(1):107–14.

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