Spine curvature data measurement and its application on product development

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Abstract-Human Spinal Column an important structure that provides strength and support to the entire upper body. The entire vertebral column is divided into Cervical, Thoracic, Lumbar, Sacrum, and Coccyx. The normal spine curvature consists of cervical curve, thoracic curve, lumbar curve and sacral curve. The normal spine has an S-shaped curve when viewed from the sideways. Two alternating curves to create an S-like structure are Lordotic Curve (Lordosis) and Kyphotic curve (Kyphosis). It has been suggested that deviations in one or both of these variables may increase a person’s risk of developing back pain.

Human spine curvature data are required in various fields including to study how heavy school bags affect posture/curvature of school-going kids, spine curvature changes due to aging, posture changes with pregnancy, upper body posture changes due to mobile phone use, body posture changes due to sitting posture/office ergonomics, etc. Besides, the human spine curvature data are required for product development such as a mattress, chair, automobile seat, pillow, rehabilitation pads, school bag, baby carrier, assistive product for pregnant women/elderly, etc. The purpose of this study is to investigate the importance of spine curvature data measurement and its applications on product development.

1. Introduction
The Vertebral Column or Backbone or Spine is one of the critical parts of the Axial Skeleton. The complete vertebral column is divided into five different parts, namely, Cervical, Thoracic, Lumbar, Sacrum and Coccyx [1]. These vertebrae are arranged in curves to create an S-like structure as Lordotic Curve (Lordosis) and Kyphotic curve (Kyphosis). Human spine provides stability and support to the entire body and assists for sitting/standing and bending/twisting without any trouble to the spinal cord. Deviations in one or both of these variables may increase a person’s risk of developing back pain. Currently, a large number of people working in IT services, business solutions and administrative work, etc., spending much time seated or in standing position. Continuous seating and standing position may create a spinal discomfort and back pain. When a spine is loaded over a long time, the time required to return the neutral position is high compared to holding time [2]. The weighty school bags may develop back pain for school going children and adolescents because of continuously carrying the bags for a prolonged period. As a result, there is little relationship between carrying school bags and back pain [3]. The discrepancy between anthropometry of the students and design of school furniture may cause to musculoskeletal disorders. This may reduce student academic

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performance [4]. Due to ageing spine curvature angles like cervical curve, thoracic curve, lumbar curve also changes and spine mobility decrease. The change in spine curvature angles affects the centre of gravity, leading to spine posture imbalance problem for aged people. Change in spine curvature angles and spine mobility may negatively affect the quality of life and lower back extensor strength of the older people [5]. Back Pain is the most common problem for pregnant women occurring nearly 50% of pregnant women. Pregnant woman experiencing four times higher back pain than the non-pregnant woman. The capacity to work and sleep can be significantly affected because of back pain during the pregnancy period [6]. Nowadays people usage of mobile phones, laptops, tablets, and personal computer has increased. Continuously if working on laptops and mobile phones may damage the spine posture, particularly in the cervical region, due to continuous loading of cervical posture angle increased that will give a negative impact on cervical lordosis [7]. Many young people are spending more time on mobile phones or laptops and less timeoutside playing. As a result, it increases the risk of musculoskeletal pain and injuries, particularly in the upper body posture and neck. There is a positive relationship between neck flexion and force acting on the neck; neck stress value may be increased from 5 kg (No flexion) to 27 kg (at 60-degree neck flexion) [8]. The purpose of this study is to explore the need for spine curvature data measurement to reduce back pain in various fields and its applications on product development.

2. Method
2.1. Literature review
PubMed database was selected for article searching and limiting to last 15 years. The following keywords are used for search including Spine Curvature data, Sitting/Standing Posture, Low Back Pain, Spinal Loading and Office Ergonomics (Fig. 1). The review results are represented in Table 1.

Figure 1. Methodology adopted for literature survey.
Table 1. List of articles.

| S. No | Articles details | Key concept |
|-------|------------------|-------------|
| 1. | Harbour Singh and Lakhwinder Pal Singh, 2018 [9] | Study the Musculoskeletal disorders and analyze the indication of pain the employees working in the insurance office. |
| 2. | Hamidreza Mokhtarinia et al., 2019 [10] | Investigated the effectiveness of the new Tehran Back Belt on healthy people. |
| 3. | Jennifer Anderson et al., 2019 [11] | Explained the range of standing work-based activities for various professions like chefs, veterinary surgeons and office workers. |
| 4. | Corlett EN, 2006 [2] | Major interactions of the spine, sitting posture and impact on seat shape, backrest, work surface design. |
| 5. | Yuji Kasukawa et al., 2009 [5] | Impact of spinal curvature, spinal mobility and back extensor strength falls for elderly people. |
| 6. | Eui Seok Lee et al., 2014 [12] | Verify the changes in lumbar sagittal alignment for elderly people with different positions (standing, supine, and various sitting postures) |
| 7. | Huan Gong et al., 2019 [13] | Different standing body posture changes occurring in ageing in sagittal plane for men and women. |
| 8. | Naoki Takeda et al., 2009 [14] | Analyze the spinal sagittal parameters and segmental disc angles for elderly people. |
| 9. | Jakub Michoński et al., 2016 [6] | Developed a new concept based on 3D shape measurement, or surface topography, systems for monitoring spine curvature during pregnancy. |
| 10. | Wojciech M. Glinkowski et al., 2016 [15] | 3D surface topography method to access spine angles and static postural changes among pregnant women |
| 11. | N. Okanishi et al., 2012 [16] | Comparison of Spine curvature angles with pregnant and non-pregnant women. |
| 12. | Abdullah Assiri et al., 2019 [3] | Adolescents back pain and related factors |
| 13. | Ademola James Adeyemi et al., 2019 [4] | Investigated the ergonomic discrepancy between classroom furniture and the students’ anthropometry data. |
| 14. | J.M. Brewer et al., 2009 [17] | Degree of ergonomic mismatch between School furniture and students body dimensions |
| 15. | Shyam Vinayak Ashtekare et al., 2018 [18] | Reducing School Beg Loads |
| 16. | Ahmet Öğrenci et al., 2018 [7] | Investigated the relationship between use mobile phones and cervical lordosis |
| 17. | Kartheek Reddy Syamala et al., 2018 [8] | Proper support can reduce musculoskeletal pain and injuries, particularly in the upper body posture and neck during mobile phone use. |
|   | Authors                                      | Title                                                                 |
|---|---------------------------------------------|-----------------------------------------------------------------------|
| 18| Kimberly A. Szucs et al., 2018 [19]         | Comparison of the upper body and limp posture with the handheld devices |
| 19| Eugenia H.C. Woo et al., 2016 [20]          | Impact of various electronic devices on musculoskeletal problems among university students |
| 20| Kim Bergholdt et al., 2008 [21]             | Waterbed, Foam mattress, Firm mattress relative effect of back pain with chronic low back pain patients |
| 21| Hyunja Lee et al., 2006 [22]                | Polysomnography study for a different type of mattress                |
| 22| Vincent Verhaert et al., 2011 [23]          | Investigated how spine posture affects the quality of sleep            |
| 23| Pradip Kumar Rayet et al., 2012 [24]        | Improve the layout of a manually-operated Electrical Overhead Travelling crane cabin |
| 24| Deepa Vinayet et al., 2012 [25]             | Reduction of musculoskeletal problems in quilt manufacturing unit by ergonomically designed work station |
| 25| Aleksandraet al., 2017 [26]                 | Compared sitting posture changes an adjustable office chair with a backrest to an adjustable saddle chair |
| 26| Leila Vakili et al., 2016 [27]              | Common postural disorders among academic dental staff                 |

### 3. Results and Discussion

Shyam Vinayak Ashtekar et al. [18] studied on schoolbag weight reduction among two rural schools located in Maharashtra. A total of 175 (79 male and 96 female) students selected from eighth and ninth standards. As per the government recommendation, students can carry 10% of their bodyweights, but 47% of students can carry more than 10% of their bodyweights. They have concluded that reduce the daily number of subjects from six to four and constant maximum limits for each standard. Abdullah Assiri et al. [3] investigated back pain and related factors for intermediate and secondary school age adolescents in Abha City, Ascer Region, Southwestern Saudi Arabia. They have selected 876 adolescents from intermediate (439, 50.1%) and secondary schools (437, 49.9%) and age range from 13 to 19 years. They have suggested carrying One-sided schoolbag creates middle back pain among students. Ademola James Adeyemi et al. [4] investigated the ergonomic discrepancy between classroom furniture and the students’ anthropometry data. They have suggested designing the school furniture based on the students’ anthropometry data that will increase the student's comfort and safety. J.M. Brewer et al. [17] investigated the degree of ergonomic mismatch between school furniture and students body dimensions. Total of 139 students have participated in this study. They have concluded that some significant amount of mismatch between school children and their furniture and it makes a limited impact on the body discomfort.

Jakub Michoński et al. [6] developed a new concept based on 3D shape measurement, or surface topography, systems for monitoring spine curvature during pregnancy. Wojciech M. Glinkowskiet al. [15] investigated the 3D surface topography method to access spine angles and static postural changes among pregnant women. N. Okanishi et al. [16] compared the spine curvature angles with pregnant and non-pregnant women. In this study, 15 pregnant women (17-34 weeks) and ten non-pregnant women have participated, and spinal mouse used to measure the spine curvature angles. They have concluded that during pregnancy time, spinal curvature and posture may change, which may lead to low back pain and pelvic girdle pain. Ahmet Öğrenci et al. [7] had conducted a study to investigate the relationship between use computing devices and cervical lordosis angle. A group of 156 patients age group of 25-42 years have completed this study. The results of the study revealed that the use of computing devices changes the cervical spine flexion that increases the cervical vertebra problems and suggested to develop more number of ergonomic devices to reduce cervical vertebra problems. Kartheek Reddy Syamalaet al. [8] had suggested proper armrests and back support can reduce musculoskeletal pain and injuries, particularly in the upper body posture and neck during mobile phone use. Kimberly A. Szucset al. [19] had conducted a study to investigate the relationship between upper body and limp posture with the handheld devices (mobile phone, tablet, and laptop) and
21 college students have participated in this study. They have concluded that the regular use of tablet creates more harmful effects compared to other devices. Eugenia H.C. Woo et al. [20] investigated the impact of various electronic devices on musculoskeletal problems among 503 (299 males and 204 females) university students. They have concluded that the high frequency of musculoskeletal problems among university students who used various electronic devices for a long period. Vakili et al. [27] have investigated the prevalence of common postural disorders among academic dental staff (96 staffs including academic staff, residents and senior students) of Tehran University. Forward head posture and rounded shoulder postures were the major problems found among the participants. The study has revealed that hyperlordosis seemed to be more as weight increases and was found to be significant. Forward head posture and scoliosis were significantly correlated with gender. Harbour Singh and Lakhwinder Pal Singh, 2018 [9] had conducted a study in musculoskeletal disorders among insurance employees. A group of 400 employees from different offices have participated in the study. The results of the study revealed that the work-related musculoskeletal disorders, the highest level in the neck and lowest in the upper back. Hamidreza Mokhtarinia et al. [10] designed a new Tehran Back Belt for improving spinal muscle activity and investigated the effectiveness of the belt on healthy people. Anderson et al. [11] explained the range of standing work-based activities for various professions like chefs, veterinary surgeons and office workers. Kim Bergholdt et al. [21] evaluated the effectiveness of Waterbed, Foam mattress, Firm mattress with back pain in chronic low back pain patients. They have selected 1060 chronic low back pain patients and divided into three groups for one month and suggested form mattress and waterbed improves sleep more positively compared to the hard mattress. Vincent Verhaert et al. [23] investigated how spine posture affects the quality of sleep among healthy subjects. A group of 17 (9 males and eight females) normal sleepers completed the study, and they used typical sleep systems (mattress, pillows and blankets). They have concluded that a sagging sleep system affects the quality of sleep among the healthy subjects in a prone or lateral posture.

Pradip Kumar Ray et al. [24] had conducted a study on the redesign of a manually-operated electrical overhead travelling crane cabin at an integrated steel plant of India. The plant consists of 24 (15 manual and 9 remote controlled) manually-operated electrical overhead travelling cranes. Initially mismatch between the crane work station and operator it creates early fatigue to the operator. They have concluded that the new ergonomic designed crane cabin can improve productivity and reduce the risk of musculoskeletal disorders. Deepa Vinay et al. [25] investigated the reduction of musculoskeletal problems in quilt manufacturing unit. An inclinometer was used to measure the spinal posture, and polar heart monitor collects physiological parameter. The time required for making one quilt takes 6 to 7 hours, and mostly labours are working in standing position, this causes postural problems for labours. The study revealed that using the spreader table and chair reduces postural problems and improves productivity. Aleksandraet et al. [26] compared sitting posture changes an adjustable office chair with a backrest to an adjustable saddle chair. The study was conducted of 60 healthy subjects (27 men and 33 women; age limit 20 to 35 years) and used a MORA 4G system. They have concluded that sitting on the saddle chair causes the positive effect of an increase in lumbar lordosis and a significant increase in protraction of the cervical spine was observed, which would be considered as a negative effect. Eui Seok Lee et al. [12] verified the changes in lumbar sagittal alignment for older people with different positions (standing, supine, and various sitting postures). The radiological changes are compared in both lordotic and segmental angles for different age groups. The study revealed that the changed position from standing to 90° sitting decreases Lumbar lordosis and upper lumbar spine angles more flexible in the twenties when compared to sixties.

4. Conclusion

Total of 26 papers were reviewed (Table-1). All the papers concern was spinal posture because the spinal column gives strength and support to the entire upper body. Human spine provides stability and support to the entire body and assists for sitting/standing and bending/twisting without any trouble to the spinal cord. The flexibility and weight distribution of the body are achieved by the shape of
spine/spine curvatures such as cervical (lordotic curve), thoracic (kyphotic curve), lumbar (lordotic curve). Human spine curvature data are required to detect spinal deformity/diagnose irregular spine curvature. Approximately 60-80% of people experience back pain at some time in their life, and this is becoming a large socioeconomic burden in industrialized countries. This study investigated the importance of spine curvature data measurement and its applications on product development.

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