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A Review on Posture Assessment

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Abstract : *Posture is the alignment of body segments. It allows a person to be able to stand, sit, move and perform daily activities. Posture has its effect on structural, anatomical, physiological, pathological, recreational and emotional well-being of a person. It is important to study the posture of a person in order to understand various health parameters of the person. Posture has its significance throughout the growth and development of a person. Various illnesses and traumas have their effects on posture. Rehabilitation taken for certain cases need to be monitored using postural effects. Sportsmen and athletes need to be assessed for having postural abnormalities for their performance enhancement. Various approaches have been available to perform this postural evaluation. These include sensor-based approach, manual goniometric approaches, digital photography and photogrammetric approaches. This review paper illustrates the description of posture assessment, importance of posture assessment and its applications. Also, various posture assessment techniques have been explained and compared in this paper. It concludes with the limitations in current study and lists the future avenues in the field.*

Keywords – *Posture Assessment, Performance enhancement, Sports Science, Foot Arch, Spinal Posture Assessment*

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I. Introduction

Posture is defined as "the position or bearing of the body whether characteristic or assumed for a special purpose" in the Merriam- Webster dictionary. In other words, posture has been defined as the alignment of body segments at a particular time [1]. Posture explains how one's body is positioned while standing, sitting or lying down. Anatomically, posture is nothing but alignment of musculoskeletal system in a particular way so as to allow required range of motion (ROM) at each joint. Posture has a vital role to play in our daily life. By maintaining good posture, stress is properly distributed to the intended muscles and ligaments. Due to which the muscles are allowed to work efficiently and as intended, which in turn decreases wear and tear of joints. When the muscles, joints and ligaments are working as intended, all other vital organs are able to remain in proper position and the nervous system is able to function normally. There are added advantage of a good posture as- boosted self-confidence, efficient breathing, improved circulation, and overall efficiency in performance.

Various factors affecting posture include Structural and Anatomical parameters, Age, Physiological factors, Pathological factors, Occupational factors, Recreational factors, Environmental factors, Social and Cultural factors and Emotional factors [2].

Posture validation, or posture assessment, refers to the act of applying a set of rules to the posture data to provide an assessment. While assessing posture, overall stance of the body is examined, alignment of body parts is checked. Bone structure is assessed for any abnormality and damage. Appearance of joints is checked for their neutral, resting position, alignment, swelling, angles and range of motion. Muscles are assessed to check if there is equal bulk on left and right side of the body. It is checked if there is any noticeable hypertrophy or atrophy anywhere. Muscle tone is checked. Skin is examined for any inflammation, discoloration or dryness. Scars, blemishes and bruising is checked. Physical attitude of the person is checked. It is observed if the subject under assessment is looking comfortable or not, it is checked if the subject appears to be able to maintain the posture with ease or not, are there any areas of tension in the body etc.

The main reasons for carrying out postural assessment are to acquire information, save time, establish a baseline and to treat holistically. Performing a postural assessment gives us more information about the patient. A second reason for carrying out a postural assessment is that in the long run it saves time. It may reveal facts that are pertinent to the client's problem that might otherwise have taken longer to establish. The relationships among body parts are more difficult to assess when someone is lying down to receive treatment, but suddenly become obvious when they stand [2]. Another reason for performing a postural assessment is that it helps you to establish a baseline i.e. a marker by which you might judge the effectiveness of your treatment. Lastly, including

analysis of posture as part of assessment, it offers a complete service in keeping with the idea of treating people holistically and not compartmentalized.

The various applications of postural assessment include: Clinical Applications, Applications in the field of Sports, Physiotherapy Applications and Applications in Personality Building. Clinically, Posture assessment can be beneficial for diagnosing any occurrence of any trauma, problems associated with joints and body angles. Muscular imbalances can be diagnosed using the assessment. Any pain if it is caused due to the faulty posture, can be assessed and accordingly preventive measures can be suggested. Sports Scientists can make use of the postural assessment to analyze the posture and body tendency of the sportsmen in order to minimize the injuries, prevent the accidental deaths. Assessment can be utilized in order to enhance their performance, develop new skills etc. Physiotherapists can use postural assessment software to determine body type of a person, to perform body composition analysis, to determine foot arch type. Anatomical deformities like Lordosis, kyphosis, scoliosis, genu varum, genu valgum etc. can be diagnosed using the assessment. Any distress caused due to wrong occupational posture habits can be detected with assistance of the postural assessment. A good personality requires a good posture. The assessment can be useful for maintaining proper posture and walking pattern of the people under training.

I. Effect Of Posture On Various Health Parameters

At every age, posture has its significance on well being of a person. Posture also changes as stated above due to various health conditions and physiological factors. Various factors affecting posture include [3] :

i) Structural or anatomical factors- for e.g. Scoliosis in all parts of spine, discrepancy in the length of the long bones in upper or lower limb, extra ribs, extra vertebrae etc.
ii) Age- Posture changes considerably as we grow into our adult forms
iii) Physiological factors- Posture changes temporarily in a minor way when we feel alert and energized as compared to when we feel subdued and tired. Pain or discomfort may affect the posture, physiological changes caused due to pregnancy are usually temporary but could result into permanent, compensatory postural change.
iv) Pathological factors- Illness and disease affect our postures especially when bones and joints are involved. Pain can lead to altered postures as we attempt to minimize the discomfort. Mal-alignment in the healing of fractures may sometimes be observed as change in bone contour. Certain conditions may sometimes result into increase or decrease in muscle tone.
v) Occupational factors- There will be postural differences between a manual worker and an office worker, and between someone active and someone sedentary.
vi) Recreational factors- Depending on regular habits, practices and hobbies, there could be difference in posture.
vii) Environmental factors- In various environmental conditions, in order to adopt to the change in conditions, posture may get affected. For e.g. in cold posture is different as compared to in heat.
viii) Social and Cultural factors- People who grow up sitting cross legged or squatting develop postures that are different from those who grow up sitting on chairs.
ix) otional factors- Usually posture sub-consciously adopted to match certain moods is temporary. But in certain cases, it persists if the emotional state is habitual.

This section illustrates the importance of posture changes on age, due to performance, hobby and occupational conditions, in sportsmen and athletes, in case of traumas and injuries and during rehabilitation phase.

a. Posture Importance in Infants

During infant phase, the posture of babies indicates the health condition of the babies [3]. Babies with some underlying syndromes or anomalies show abnormal posture. For example, infants with autism [4], or infants with Down's syndrome [5] will have significantly different posture as compared to healthy new born. As the toddlers start to walk, it is important to monitor their posture for it determines their healthy growth [6]. The habit of sitting also has its pros and cons. Children who sit with legs folded in "W" shape [7] are prone to have abnormal posture after they grow.

b. Posture Importance in Children and Young adults

Similarly posture has its own effect on children as well. Body posture failures in children constitute many underestimated health problems [8]. The reduction in cardio-respiratory efficiency, decreased vital capacity of the lungs, degenerative bone and low back pains, as well as the displacement of the internal organs are just some of the consequences of untreated incorrect body posture [9]. The increase in the prevalence of overweight and obesity among children and adolescents has drawn attention to additional health complications which may occur in this population. Most of the studies concern cardiovascular complications. Subclinical organ damage seen in children with obesity, manifested in hypertension, left ventricular hypertrophy, and

dysfunction, as well as thickening of intima-media carotid arteries, can all cause worse cardiovascular adaptation to physical effort and faster fatigue, resulting in the decline in physical fitness [8]. Also, the foot plays an important role in maintaining a static position and providing a stable base when performing functional activities. Flexible flatfoot is one of the most common conditions seen in pediatric orthopedic clinics. The foot arch begins to develop when a child starts to take weight on their legs, and it keeps developing during the first decade of life. The prevalence of flexible flatfoot is 21-57% in children at preschool age [10]. School children carrying heavy baggage on their back also leads to various postural problems [11] and may result in even serious health conditions. Due to the heavy weight on back, there may be ill effects on the spine which will result into temporary or permanent chronic postural problems. Postural change occurs continuously throughout the entire time of ontogenesis, with critical periods at school age and puberty [12]. Research of individual developing adolescents generally forms a major challenge [13,14]. Puberty is accompanied by major maturational physical alterations in body shape and dimensions, and substantial brain changes [15-16]. Thus, in general it implies that posture has a vital role to play in the growth and development of a human being ever since its infant phase till adolescence. Study of posture and postural parameters will help in study of growth of the human being at different age intervals. On the other hand, posture in adults reveal other important details of health conditions.

c. Posture importance in elderly people

The aging process modifies normal postural alignment, and flexed posture commonly increases with age. Thoracic kyphosis and protrusion of the head, and in more severe cases, knee flexion, characterize flexed posture [17]. Flexed posture (FP) pathophysiology in the elderly is most likely multifactorial and can be associated with low bone mineral density and consequently vertebral fractures, and also degenerative alterations of intervertebral disks [17]. Similarly, measurement of foot posture is widely considered to be an important component of musculoskeletal examination in clinical practice and research, as variations in foot posture have been found to influence lower limb gait kinematics, muscle activity, balance and functional ability, and predisposition to overuse injury [18].

d. Posture importance in Sportsmen and Athletes

Postural stability is deeply linked with sports injuries, and copious evidence exists indicating that postural stability is greatly reduced by sports injuries [19]. In addition to previous injuries, postural stability may be affected by changes in the level of activity, as well as by its type, intensity, and volume, which constitute a risk of injury for athletes [20]. From a physiological point of view, the main cause of deteriorated postural stability as a risk factor is an alteration in the neuromuscular control strategy, which increases intersegmental joint forces and consequently increases the development of forces involving ligaments, tendons, and muscles [21]. Lower extremity injury may negatively affect postural control and contribute to the incidence of future injuries [22]. The high impact, dynamic nature of running combined with the task constraint of a narrow base of support poses a significant postural control challenge. It is possible that underlying postural control deficits may partly explain altered mechanics commonly observed in runners with injury [23]. Also, Stabilometry is widely used to study the orthostatic postural control in sport science [24]. Maintaining balance during the natural orthostasis is a complex task for humans because of the intrinsic instability of the position; stabilometry does not measure balance but the stability properties of the human system while keeping a balanced standing position, because balance does not correspond to an absolute reality but it is a position-specific skill

e. Posture importance in people with different health conditions

Posture in healthy human beings and posture in person under ill health conditions differ drastically. To give an example, person will have different way of sitting/ relaxing when having simple high fever or severe cough and cold. This gives insights on how the posture will behave while some serious health conditions. Ankylosing spondylitis (AS) is a major chronic rheumatic disease that predominantly affects axial joints, determining a diffuse stiffness and with the advanced stage producing a rigid spine from the occiput to the sacrum, for a chronic process of inflammation of the fibrous connective and bone in the tendon and ligament insertions [25]. Hence, the clinical manifestations of AS are pain, stiffness, fatigue, reduced spinal mobility and respiratory restriction. Objective clinical signs of AS are precocious loss of lumbar lordosis, increased dorsal kyphosis and inversion of cervical lordosis, abdominal relaxation for diaphragm breath, hip flexion contracture and consequent knee flexion compensation [26,27]. Spinal kyphosis in AS subjects has also been associated with a forward and downward shift of the centre of mass (CoM) of the trunk in the sagittal plane, thus inducing a forward and downward shift of the body's CoM with respect to the base of support [25]. There also has been seen presence of biomechanical alterations during walking in a group of AS [28]. Loss of balance in AS patients may be associated with severe joint deformities and poor posture. Moreover loss of balance may increase the risk of falls [25]. Taking another disease, Asthma is a chronic respiratory disease characterized by increased

bronchial responsiveness, reversible airflow obstruction, and bronchial inflammation, which is considered the main physio-pathogenic aspect of the disease. In adults with asthma, the changes in respiratory mechanics and obesity interfere with body posture [29]. In adult patients with asthma, there is a close association between postural deviations and airways obstruction variables, including 'air trapping' and hyperinflation. Also, both respiratory muscle strength and body composition contribute to the abnormalities in body posture. Apart from pathological conditions, even injuries are an important source of postural variations. Traumatic brain injury (TBI) results from a direct or indirect blow to the head that results in neuropathologic changes [30]. Clinical observation of concussed individuals reveals impaired postural control in the days immediately after injury. The effects of impaired postural control have been shown to be large, with impaired sensory integration postulated as the source of imbalance [31]. Similarly, physical Injury to the anterior cruciate ligament (ACL) is associated with knee instability, altered knee joint loading and impaired neuromuscular control, defined as the ability to produce well controlled movements through coordinated muscle activity [32]. Lower limb injuries when studied [33], showed to have effect of Foot Posture Index on malalignment and pathological proximal rotational problems on rear foot. Above mentioned are just a few examples on how the posture changes as per the injuries.

f. Posture importance in person under rehabilitation

Rehabilitation usually is followed by a post-operative care, post accidental physiotherapy or post injury prognostic recovery. While the person is under rehabilitation, it is important to monitor the effect of the treatment given to the patient. This enables to ensure the correct execution on the rehab program or the exercise prescribed. Monitored rehabilitation exercises have been shown to be more effective than practice without feedback [34]. When patients perform these prescribed exercises at home it is important that at-home exercises are performed correctly to ensure the benefit of the rehabilitation regimen [35].

II. Important Posture Parameters to Assess

From a clinical point of view, knowledge of customary standing positions among healthy young adolescents is of primary importance. Large cohort studies analyzing children and adolescents reported reference values of spinal and pelvic sagittal parameters. Other studies have characterized the changes in sagittal plane alignment during growth. A potential limitation of the majority of these studies [12] in characterizing standing postural mechanisms, relates to information on the alignment of the spinopelvic axis in the context of the whole body. External pelvic motion has a critical role in maintaining the balance of the spinopelvic axis However, few attempts have been made to include assessment of the orientation of the lower limbs in space. Fig. 1 shows the locations of marker points used for one such postural assessment study.

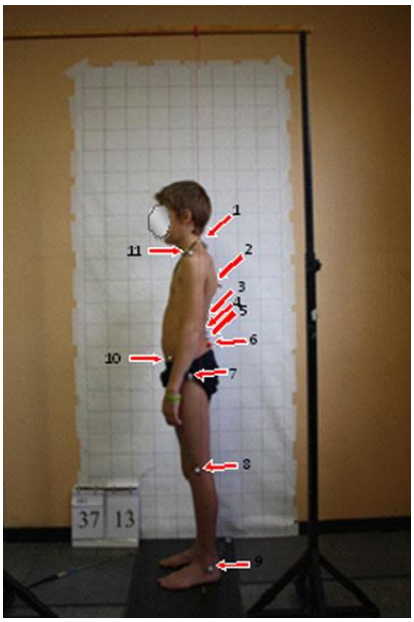

Fig. 1: Placement of reflective markers. 1 spinous process of the 7th cervical vertebra, 2 thoracic apex, 3 inflection point, 4 lumbar apex, 5 spinous process of the 5th lumbar vertebra, 6 posterior superior iliac spine, 7 greater trochanter, 8 lateral femoral condyle, 9 lateral malleolus, 10 anterior superior iliac spine, 11 acromion (most lateral

aspect)

The strength and length of muscles involved in joint motion must be balanced. The balance is based on force couple (two or more translatory forces that in combination produce rotation) principle among muscles involved in the three cardinal planes of motion. When a force couple is out of balance, the segment moves off its axis of rotation and there is faulty joint motion. The head, trunk, shoulders and pelvic girdle serve as the foundations, from which forces are directed to the limbs. Postural faults can be used as guidelines for identifying alterations in muscle and ligament length. This may occur when one muscle groups become tight and the antagonist elongated. Synergistic muscles around a joint may be unbalanced as well as the agonists. Minor alignment faults in posture limit motion and lead to tightness of muscles and other soft tissues. Muscles that are elongated often develop their maximal force in the stretched position and are weak in the normal physiological position. Alignment of body segments should be observed while the person is standing still and during such movements as walking, to detect faulty patterns of muscle activity and joint mobility. The better the quality of movement and the better the alignment of gravitational forces through joint's axes, the better is the sequence of motion. When postural alignment improves, imbalances are minimized.

systematic approach to postural analysis involves viewing the body's anatomical alignment relative to a certain established reference line. This reference (gravity) line serves to divide the body into equal front and back halves and to bisect it laterally. In preparing to carry out postural assessment, the examiner should be aware of factors that will enhance the success and validity of the examination process. These factors are:

1. Postural assessment must be performed with the subject minimally clothed, in order to ensure a clear view of the contours and anatomical landmarks used for reference.
2. The examiner should instruct the subject to assume a comfortable and relaxed posture.
3. Subjects who use orthotic or assistive devices should be assessed with and without them to determine their effectiveness in correcting posture.
4. The examiner should note relevant medical history and other information that may account for certain postural abnormalities. Important information includes:

- Any history that accounts for present postural abnormalities.
- A complete description of present symptoms.
- All previous treatments for the presenting postural complaints, including orthopedic and neurological therapy.
- The upper limb dominance of the subject, which is often responsible for symptomatic postural deviations.

Postural examination is most commonly performed by assessing the body's alignment in lateral, posterior and anterior views.

III. Various Approaches Towards Postural Assessment

Posture evaluation using visual observation method is widely employed and still famous especially due to its low cost, however it has a limitation that it gives only details and detect deviations [36]. In this method, subject is made to wear minimum clothes and observations are made from the front, back and side view and are analyzed according to predetermined guide [37]. For example, in the ideal sagittal alignment, the gravitational line passes through the external acoustic meatus, the bodies of the cervical vertebrae, the tip of the shoulder, the mid-point of the thorax, slightly behind the hip joint, slightly in front of the knee joint and immediately preceding the lateral malleolus. X-ray examinations (XR) are routinely used to measure curvatures of the vertebral column and to analyse vertebral conditions [38]. X-rays have been considered the golden standard regarding the observation of posture deviations [39], despite being an invasive examination in which the individual is exposed to radiation [40]. The radiation used in X-ray equipment has an accumulative effect in the organism, and each new incidence increases the health risk. The negative effects can be seen soon after exposition (erythema, tissue necrosis), or after a long period of latency (6–25 years), even after low exposition, involving chemical damage to the DNA molecules, increased cancer risk and risk of genetic defects [41]. X-ray studies are also limited because they are done without calibration, and errors can be found when comparing the same measurements from different X-ray images [42]. The flexible ruler is a non-invasive instrument that provides a low-cost quantitative evaluation of spinal curvatures in the sagittal plane, and is easy to use and transport. It is 60 cm long, made of plastic coated lead, and is only flexible in one plane. After molding to the individual's spine, the mold is transferred to a sheet of paper where the values in millimeters (length and height) of the spinal curvatures are calculated. Studies have shown excellent levels of inter- and intra-evaluator reproducibility and strong correlation between the two methods (flexible ruler and X-rays). Although the relative mean differences between the flexible ruler and radiologic data are small for both the thoracic and lumbar curvatures, the range of values is quite wide, the symmetrical distribution of the values for both curvatures suggesting a random error [43]. The laser acquisition system used in scanners, is one of the most precise devices [44,45], but is very expensive and requires that the person being measured remains completely still throughout the measurement. Scanners consist of a 3D (three-dimensional) optical measuring system that produces a digital copy of the surface geometry of a human body [46]. The laser is fixed in the equipment and

the video cameras move step by step scanning the individual's body. The triangulation sensors used move in different directions in the horizontal (total of 360°) and vertical (from top to bottom) planes, and once the values of the X and Y directions are known, they are moved one step in the Z direction (depth). The object is thus mapped bit by bit using the information of the distances between the points [47]. Photography or filming methods enable clinicians to detect postural changes with time, and inter-relate various body parts through measurements with specific software. Photography or filming are low cost methods which are easy and quick to use [48], but they require several methodological steps such as the choice of environment, camera position, resolution of the image captured, and the use of anatomical markers [48,49] to standardize the photos/films and prevent or reduce distortions and measurement errors. Moreover, there are some limitations inherent to the instruments, such as the analytical variations resulting from the choice of an image that does not correspond exactly to the anatomic plane under evaluation [50], which is called parallax. Since photography provides a two-dimensional image, only the part of the body that is in focus has true measurements, while the other parts might have their dimensions distorted by the effect of parallax [51]. Software is currently available to process two-dimensional images, captured simultaneously by several cameras (between 3 and 6), and reconstruct them in 3D for analysis [52]. However, this method is more complex, adds cost, and requires calibration, and is not usually available for analysis in surgeries and clinics [48].

IV. Conclusion

Posture has its implications of the well being of a person. In this paper we have broadly seen the effect of posture variations on Infants, Children, Adolescents, Adults and older people. The paper also discusses effect of posture abnormalities on Sportsmen, people with various health conditions and person under rehabilitation. Later, the outline of postural assessment is presented. In order to assess complete body, there are over 30 points which are fixed apriori. Posture validation, or posture assessment, refers to the act of applying a set of rules to the posture data to provide an assessment. While assessing posture, overall stance of the body is examined, alignment of body parts is checked. Bone structure is assessed for any abnormality and damage. Appearance of joints is checked for their neutral, resting position, alignment, swelling, angles and range of motion. Muscles are assessed to check if there is equal bulk on left and right side of the body. It is checked if there is any noticeable hypertrophy or atrophy anywhere. Muscle tone is checked. Skin is examined for any inflammation, discolouration or dryness. Scars, blemishes and bruising is checked. Physical attitude of the person is checked. It is observed if the subject under assessment is looking comfortable or not, it is checked if the subject appears to be able to maintain the posture with ease or not, are there any areas of tension in the body etc. The paper also describes the various techniques implemented in order to assess the posture. From the research review performed extensively, it was found that the field under study is still under its developmental stage. Some of the observations that were drawn from the review conducted are listed below.

The research articles when searched using the keywords Posture Assessment/ Photogrammetry/ Digital Photography in Posture evaluation are very limited and most of the obtained articles are irrelevant. The articles that were obtained are mostly review articles. Articles reviewed are mostly validation studies and experiments conducted to prove cause and effect relationships. None of the article obtained talk about the methodology and discuss the technical details about the process of postural assessment. The papers have mentioned the names of software's that are used for conduction of the assessment. However, while searching on those softwares, some of them are not available on internet while some are paid softwares. Some of the mobile applications used to conduct posture assessment are in the process of filing patents and also are chargeable for use. Based on above observations, and based on reviewed relevant literature the research gaps are seen. Currently available softwares are commercial and need to be purchased for carrying out the validation too.The available methods that make use of photography/ photogrammetry are semi-automated as they need some manual markings to be entered by the doctor / therapist. Current methods that are based on Corel Draw/ AutoCAD/ Photoshop etc need to be calibrated manually by entering the regions like eyes, lips, shoulders etc. Other software-based methods that make use of images need markers to be placed on the patient either prior to taking the images or they need soft markers to be placed on the patient image by doctors / therapists/ practitioners. The digital photographs that are considered in the reviewed literature is not customized for Indian culture due to socio cultural barriers. None of the study includes the whole-body posture assessment. None of the literature includes digital photography technique for foot arch assessment along with the whole-body posture assessment. As the study on postural assessment softwares is a longitudinal study, it is reflected from most of the literature that most of the research is still ongoing and hence we have not received any solid research article that put light on photographic postural assessment procedures.

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