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Differences in body positional bilateral symmetry between stance and supine positions, and the impact of attention and awareness on postural symmetry

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ABSTRACT

Background and purpose: Postural asymmetries may cause structural pathological conditions and impaired movement pattern. The influence of body position and awareness towards symmetry has not yet been elucidated. The aim of this study was twofold: First, to compare the body positional bilateral symmetry between standing and supine positions, and second, to examine whether the awareness to symmetry can modify posture perception and body positional bilateral symmetry.

Methods: We analyzed the degree of anterior postural alignment symmetry of 34 healthy subjects by photogrammetric method (three photographs in a standing position and three in a supine position). Each photo captured different state of awareness: Subjective Comfortable Posture (SCP), Subjective Perceived Symmetrical Posture (SPSP), and Guided Posture Protocol (GPP).

Results: The standing position increased the symmetrical alignment of the neck ($p < 0.013$) and the upper limbs ($p < 0.011$). However, the supine position demonstrated increased symmetrical alignment of the upper trunk ($p < 0.019$) and the feet ($p < 0.002$). In the standing position, GPP showed greater symmetry of the neck ($p < 0.022$), the shoulders ($p < 0.014$), the thorax midline ($p < 0.009$), the upper trunk ($p < 0.000$) and the upper limbs ($p < 0.029$). No significant changes were observed in the supine position between the three states of awareness.

Conclusions: Study results indicate that the supine position shows greater degree of upper trunk's symmetrical alignment than the standing position. It also indicates that while standing, focusing attention into symmetry improves body positional bilateral symmetry. These results might have clinical implications when working with patients who suffer from asymmetric posture.

1. Introduction

Bilateral postural symmetry is considered a cue to an individual's genetic quality, including health. [1] It is also the basic requirement for efficient movement [2]. Structural and functional asymmetry may cause pathological posture and impaired movement pattern [3–5]. Although it is believed that the ideal anterior postural alignment in healthy adults is characterized by bilateral symmetry [2], studies have shown small postural asymmetries and asymmetrical movement patterns on healthy adults [6,7]. These asymmetries increase among subjects with Adolescent Idiopathic Scoliosis (AIS) [8], Cerebral Palsy [9], and Stroke [3]. Establishing bilateral symmetry is a complex task influenced by external factors (such as gravitation) and modified and controlled by internal factors (the sensory and musculoskeletal systems) [2,10–12]. Small body asymmetries might lead to pain, and malfunction [13,14]. Therefore, the clinical examination and treatment of musculoskeletal aches and pains often include consideration of postural bilateral symmetry/asymmetry [2]. Establishing ways to enhance body positional symmetry is of great importance to the clinical world.

Gravitation has an impact on body positional bilateral symmetry. For example, it has been shown that the percentage of scoliotic curve correction was between 19%–31% when changing from the upright to the supine position. [15,16] However, comparing the anterior postural symmetry of adult healthy subjects in standing and supine position has not yet been done.

Body awareness and attention have been studied extensively in relation to perception of posture and motor control. [17–20] Body awareness is the subjective, phenomenological aspect of proprioception

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and introception that enters conscious awareness and is modifiable by mental processes. It is related to body scheme, tactile and proprioceptive senses. Attention is a process that entails focusing on conscious awareness, thereby providing heightened sensitivity to experiences [17–20]. Bullok-Saxton [21] showed that among normal, young adult subjects the perception of posture, and therefore postural alignment in natural stance, remains constant for at least two years.

The enhancement of body awareness and focusing the attention on different aspects of the body by verbal instructions, are part of the therapeutic process in clinical practice and have been studied in stroke patients, AIS and amputees. [3–5,22,23] Nevertheless, so far, it has not been established whether or not verbal instructions can direct attention and awareness towards greater positional body symmetry.

Therefore this study is designed to examine the influence of gravitation (upright vs. supine position), attention, and awareness (in three different conditions) on body positional bilateral symmetry.

Based on previous research of scoliotic curvature [15,16] we hypothesized that we will find greater symmetry of the trunk in supine position compare with standing in healthy subjects. If indeed we will find differences in body symmetry between upright vs. supine position, or between the three states of attention and awareness, this could serve clinicians for the treatment of body bilateral asymmetries.

2. Methods

2.1. Study population

A total of 34 healthy adults were evaluated in one session at the Department of Anatomy and Anthropology, Sackler Faculty of Medicine, Tel Aviv University. Exclusion criteria included: 1) subjects older than 50 years or younger than 20 years (in accordance with Chevillotte et al. [24] and Been et al. [25]); 2) current diagnosis of musculoskeletal disorder or chronic disease; 3) current physical aches or pains; 4) leg length discrepancy greater than two centimeters (in accordance with Knutson [26]). The institutional ethics committee approved the study.

2.2. Postural analysis by Photogrammetric method

Anterior postural alignment was evaluated in standing and supine positions by PAS/SAPO (Postural analysis by Photogrammetric method) free and open source postural analysis software. [6,27] The anterior postural alignment was captured by the use of two digital cameras. The first camera, which was used for photographs in the standing position, was a Canon PowerShot A700. The camera was mounted on a 1-meter high tripod, placed 2.5 m away from the subject. A plumb line was used for calibration of the standing position (similar to [6,27]). The second camera which was used for photographs in the supine position, was a Canon PowerShot SD 430 wireless. The camera was mounted on a lighting system device, which was attached to the wall along with a tripod head connector. The camera was placed 2.5 m above the center of a foam mat (an 8-piece puzzle mat, 240 X 120 cm). The mat was precisely placed on the floor between specific markings. The camera was positioned above the center of the mat and parallel to the plane of the mat by using a spirit leveler. The edge of one side of the mat was used to calibrate the frame (Fig. 1).

2.3. Measurement of postural variables

For each subject, 27 anatomical landmarks were identified and marked by Styrofoam balls (20 mm diameter) using double-sided adhesive tape (Fig. 2). Participants were dressed in tight fitting clothing that did not influence position of the balls overlying the bony landmarks. [6,27] Each of the anatomical points' locations was retested by an expert physical therapist (EB).

Based on the anatomical landmarks, 18 postural variables were defined using SAPO (see supplementary Table S1). Variables representing angles were measured in degrees and distances were measured in centimeters. The inclination in horizontal alignment of bilateral body parts is given either a positive or a negative value. A positive value is moving counter clockwise (right) and a negative value is moving clockwise (left), unless written differently. Zero degree represents perfect symmetry.

Since there is no true vertical reference for the supine photographs, we chose to evaluate angles that are intrinsic to the body and do not require the use of an external frame of reference – angles that are given by three or more anatomical points. Some of the angular variables of the lower limbs could not be evaluated in a supine position, and therefore were not measured in this position.

2.4. Study protocol

Each participant signed an informed consent form, and underwent a short demographic interview. After the interview, polystyrene balls were fixed. Then, six pictures (P1-P6, Fig. 3) were taken in a certain order. In the first photographic state, Subjective Comfortable Posture (SCP), the subject was instructed to stand in his/her most comfortable, natural posture (P1). After taking the first picture, the subject was instructed to lie supine in his/her most comfortable manner (P2) for the second picture. In the second photographic state, Subjective Perceived Symmetrical Posture (SPSP), the subject was asked to stand in a posture as symmetrical as possible (P3). Then the subject was asked to lie supine in a posture as symmetrical as possible (P4). For the third photographic state, Guided Posture Protocol (GPP), we offered a specific protocol which guides and focuses the subject's awareness and attention to achieve symmetrical posture, both for standing (P5) and supine (P6). The GPP protocol of symmetrical stance was modified based on the Body Cognition Method (BCM) [28] to suit the research's purposes. The protocol included the following factors: Base of support and weight distribution, the alignment of the spinal column and verticality, the alignment of the torso, the placement of the shoulder girdle and arms, the position of the head and neck (see supplementary material).

2.5. Statistical analysis

All statistical analyses were performed using SPSS (version 21). The statistical significance level was defined as $p < 0.05$. The one sample Kolmogorov-Smirnov test was used to assess the variables' normality. As all of the variables were normally distributed, we used paired sample T tests to compare between standing and supine positions, and 2*3 ANOVA Repeated Measures tests to compare between each of the perceptional states (SCP, SPSP, and GPP). Adjustment for multiple comparisons was done by the least significant difference (LSD).

3. Results

Altogether, we measured 17 females and 17 males. The mean age was 35.5 (on a 22–50 age range). For more demographic details, see supplementary Table S2.

3.1. Comparing between standing and supine positions

Table S3 (supplementary) summarize paired sample T tests comparing the postural variables between the standing and supine positions (Fig. 4).

a SCP- Subjective Comfortable Posture

When comparing between the standing and supine positions in SCP, we found that the cervical inclination angle (AbAH) changed from the left side when standing to the right side when supine, with a slight increase in asymmetry in the supine position ($p = 0.013$). Thorax

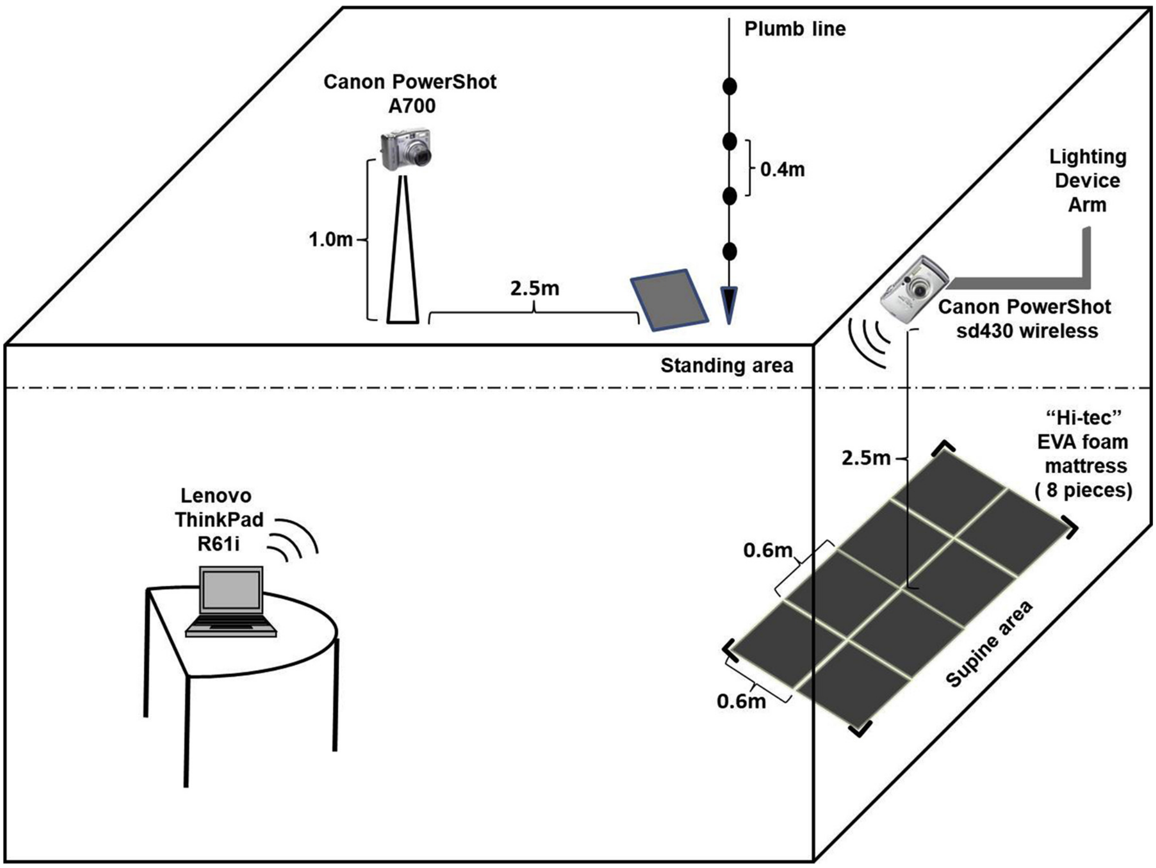
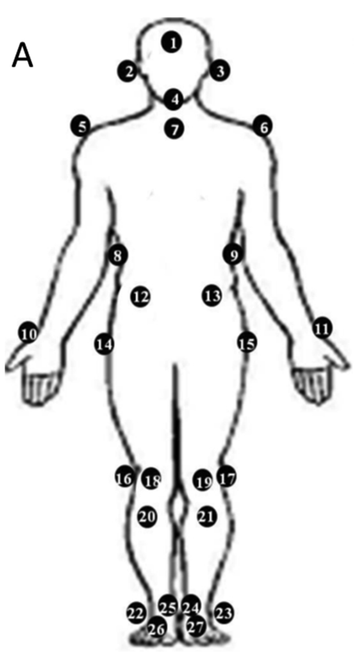


Fig. 1. Schematic illustration of the posture analysis lab.

inclination (AbAT) remained to the right side for both positions, but showed increased symmetry in supine position (p = 0.019). Feet Angle Difference (FAD) decreased in the supine position (p = 0.002). All other postural variables did not show any significant difference between standing and supine positions in SCP.

- *SPSP – Subjective Perceived Symmetrical Posture*

When comparing between standing and supine positions in SPSP, we found that the cervical inclination angle (AbAH) remained to the right side with an increased asymmetry in the supine position (p = 0.001). The asymmetry of the Upper limb Angle Difference (UAD)



B

Point	Anatomical Landmark
1	Glabella
2,3	Earlobe
4	Menton
5,6	Acromion
7	Manubrium of sternum
8,9	Thorax midline (TM)*
10,11	Styloid process of the radius
12,13	Anterior-superior iliac spine
14,15	Greater trochanter of the femur
16,17	Lateral knee joint line
18,19	Patella
20,21	Tibial tuberosity
22,23	Lateral malleolus
24,25	Medial malleolus
26,27	Point between the head of the 1st and 2nd metatarsals

Fig. 2. A Anatomical landmarks position. B Anatomical landmarks table.

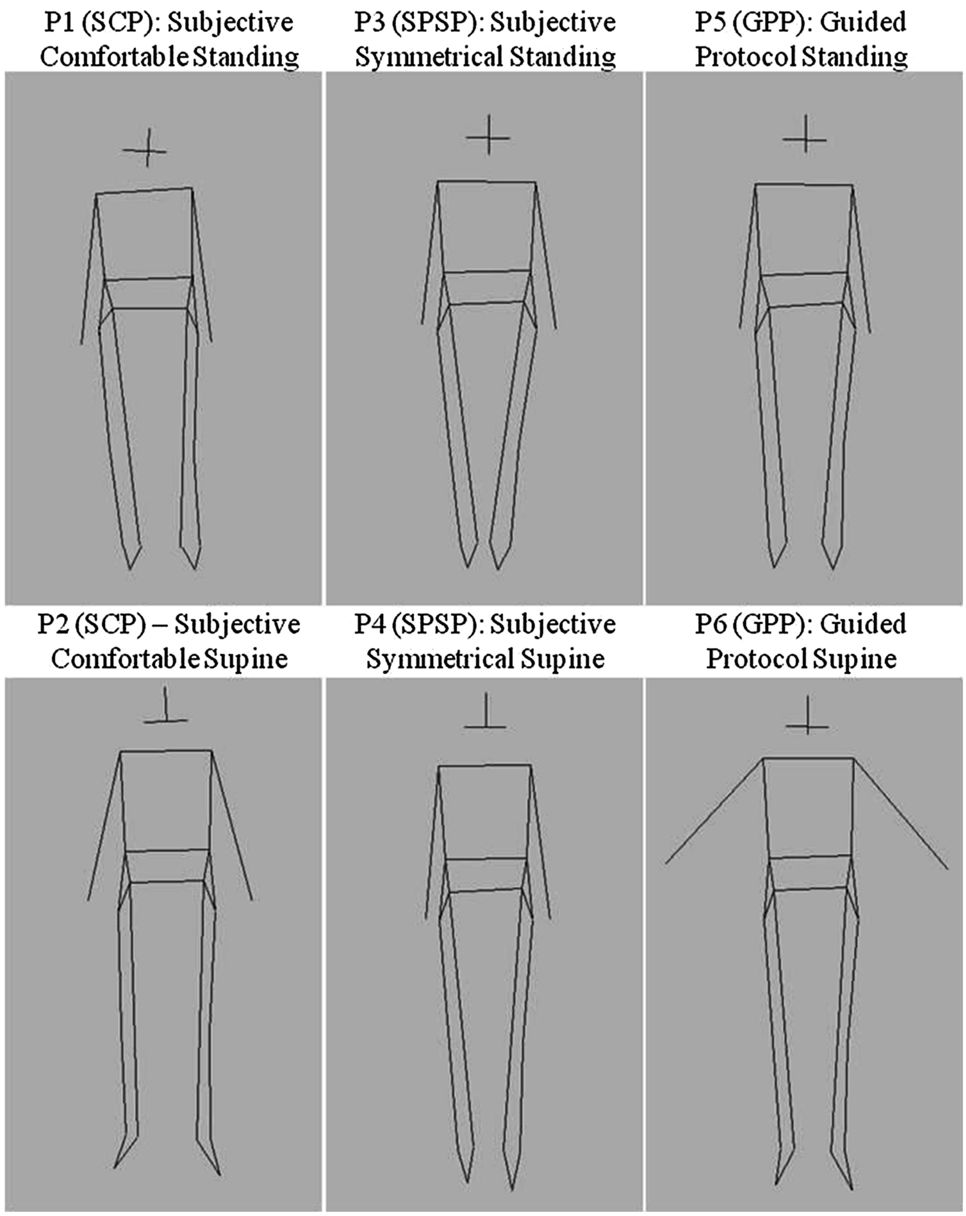


Fig. 3. The six states of perception of a subject (P1 – P6) as printed from PSAS (posture scheme analysis software) that was developed for this project. Each column represents different states of perception: SCP, SPSP and GPP. Each row represents different body positions: The first row represents the standing position and the second row represents the supine position.

was larger in the supine position than in the standing position ($p = 0.011$). Feet Angle Difference (FAD) decreased in the supine position ($p = 0.001$). Other postural variables did not show any significant difference between the two positions.

- *GPP – Guided Protocol Posture*

When comparing between standing and supine positions in GPP, the cervical inclination angle (AbAH) remained to the right side, with an asymmetry increase in the supine position ($p = 0.027$). The asymmetry of the Upper limb Angle Difference (UAD) was larger in the supine position than the standing position ($p = 0.019$). Feet Angle Difference (FAD) decreased in the supine position ($p < 0.001$). Other postural variables did not show any significant difference between the standing and supine positions.

3.2. Comparing between perceptional states

Table S4 (supplementary) summarize the results of 2*3 ANOVA repeated measures test (Fig. 5).

3.3. The standing position

There were numerous differences in the spine and the thorax: 1) When comparing between the three states of perception, we found that the degree of shoulder symmetry (AHA) is greater in GPP compared to SCP ($p = 0.014$) and SPSP ($p = 0.008$). 2) The angle between the acromia and the head (AbAH), which reflects neck symmetry, showed a change from left (SCP) to right (GPP). The degree of cervical spine symmetry is greater in GPP ($p = 0.022$). 3) Thorax Midline Horizontal Alignment (TMHA) demonstrated inclination to the left in the three states of perception. The Thorax Midline Horizontal Alignment of both SPSP and GPP was significantly more symmetrical than SCP. 4) Thorax inclination (AbAT) was more symmetrical in GPP compared to SCP

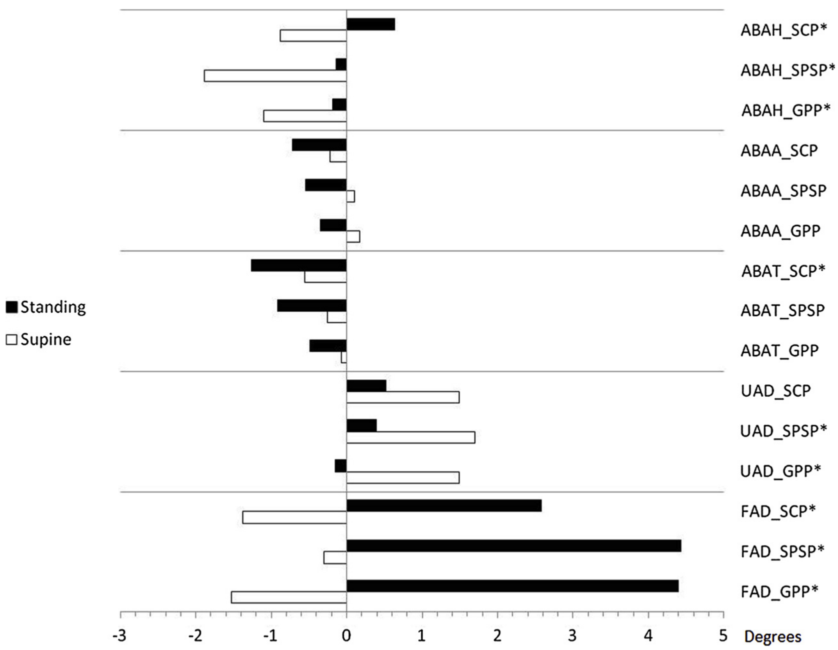


Fig. 4. Comparing postural variables between standing (black bar) and supine (white bar) positions for each state of perception. AbAH - the Angle between the Acromia and the Head; AbAA - the Angle between the Acromia and the Asis; AbAT - the Angle between Acromia and the Thorax; UAD - Upper limb Angle Difference; FAD - Feet Angle Difference; SCP - Subject Comfortable Posture; SPSP - Subject Perceived Symmetrical Posture; and GPP - Guided Protocol Posture. * represents p value < 0.05. The value of the angles is shown in degrees.

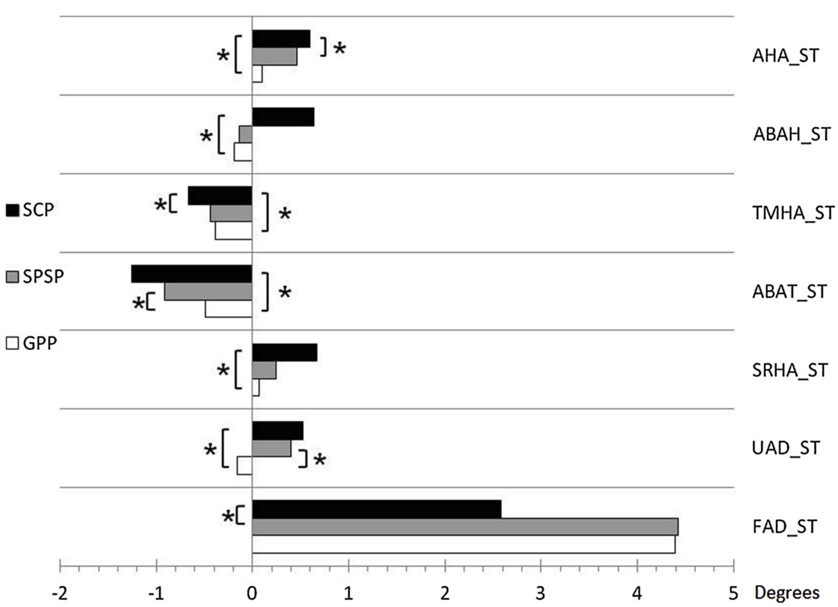


Fig. 5. Comparing postural variables between the three states of perception in the standing position. The black bar represents Subject Comfortable Standing (SCP); the gray bar represents Subject Perceived Symmetrical Posture (SPSP) and the white bar represents Guided Protocol Posture (GPP.) AHA - Acromia Horizontal Alignment; AbAH - Angle between the Acromia and the Head; TMHA - Thorax Midline Horizontal Alignment; AbAT - Angle between the Acromia and the Thorax midline; SRHA - Styloid Radius Horizontal Alignment; UAD - Upper limbs Angle Difference; and FAD - Feet Angle difference.
The value of the angles is shown in degrees. Zero angle is defined as symmetry. * represent $p < 0.05$. Adjustment for multiple comparisons: Least Significant Difference (LSD).

($p < 0.001$) and SPSP ($p = 0.008$).

Differences in upper limb symmetry between the three states of perception included: 1) The Styloid Radius Horizontal Alignment (SRHA) has a more symmetrical inclination in GPP compared to SCP ($p = 0.011$). 2) The Upper limb Angle Difference (UAD) decreased in GPP compared to SCP ($p = 0.029$) and SPSP ($p = 0.030$), indicating a higher symmetry in GPP. In the lower limb, the Feet Angle Difference (FAD) showed a significant decrease in symmetry from SCP to SPSP ($p = 0.017$).

Other postural variables did not show any significant difference in the standing position between the three perceptional states. None of the postural variables showed significant differences in the supine position.

4. Discussion

Posture and postural alignment are influenced by external factors such as gravitational forces, body position and orientation. [2,10,11] Posture is controlled and modified by internal factors, including the musculoskeletal system, somatosensory, vestibular and visual information [10]. In this study, we found that among healthy adults, postural symmetry changes between the standing and supine positions, and that the subject's awareness and attention influence postural perception, thus leading to more symmetry with the relevant instructions (in upright posture). It is important to note that postural variables are influenced by each other [26], for example, shoulder symmetry could influence styloid process symmetry. Yet, the chain of interactions between body parts, in a specific posture, is not the focus of this research.

4.1. Comparing between standing and supine positions

In the standing position, the neck and the arms showed more symmetrical alignment than in the supine position, whereas in the supine position, the upper trunk and the feet showed more symmetrical alignment than in the standing position (Fig. 4). Although the population of the current study consists of healthy adults, we found greater symmetry of the upper trunk (AbAT) when supine, in accord with previous studies that showed spontaneous correction of scoliotic curves in the supine position [15,16]. Moreover, the use of the photogrammetric method exhibits the same pattern among healthy subjects as the radiographic methods for AIS subjects [15,16]. Unlike the upper trunk, the lower trunk (AbTA) and trunk alignment as a whole (AbAA), did not show any significant difference between standing and supine positions. In supine, the upper trunk extends backwards on the floor, and the thorax is in contact with the ground (unlike the lumbar). This position decreases trunk rotation and lateral flexion that appear in standing position due to gravitational forces, encouraging more symmetrical anterior alignment [11]. Moreover, even small discrepancies in leg length (less than two centimeters), have been shown to enhance spinal asymmetry in standing positions [26]. In the supine position, leg length discrepancy has smaller impact on trunk symmetry, because the legs do not support the weight of the trunk, thus leading to greater symmetry in the trunk.

The increased head symmetry (AbAH) in the standing position compare with supine, might be the result of more accurate integration of the senses involved in perceiving the posture. Finally, the degree of arm symmetry is greater in the standing position in SPSP and GPP (but not in SCP). We assume that in SPSP and GPP, the standing position not only shows grater arm symmetry due to gravitational forces, but also enabled the subject to align the arms in a more symmetrical manner due to focusing their attention and awareness.

4.2. Comparing between Perceptional States

The comparison between states of perception for each position showed that in the standing position (Fig. 5), the upper body parts, i.e., the neck, shoulders, thorax and upper limbs are significantly more symmetrical in GPP compared to SCP. On the other hand, feet symmetry is more symmetrical in SCP compared to SPSP. Some of these postural variables exhibited gradual change between the three states, with maximum symmetry in GPP (Fig. 5). This might imply that turning one's focus and awareness toward symmetry can improve one's perception of symmetrical posture (SPSP), enhancing down to the finest details one's ability to find a better symmetrical alignment (GPP) of the upper body. Interestingly, when asked to stand in a symmetrical manner, the effect of the attention to symmetry was the opposite on the feet. The subjective symmetrical stance (SPSP) showed increased feet angle asymmetry compared to the natural one (SCP.)

None of the postural variables showed any significant difference in the supine position, between the three states of perception. This might indicate that postural symmetry perception is more accurate in an upright stance than in a supine position. Studies show that healthy adults who stand on a stable surface tend to rely on somatosensory information (70%), vestibular information (20%) and visual information (10%) [10]. There is limited knowledge regarding the contribution of the senses in keeping body alignment in supine position. A few characteristics must be considered when comparing standing and supine positions. 1) The base of support changes from solely the feet when standing to the entire posterior part of the body when supine. 2) In supine position, the geometry of body segments with reduced weight loading on the joints change the proprioceptive cues. 3) The eyesight changes from a horizontal alignment when standing to a vertical one when supine, as does the vestibular system. This affects the subjective vertical that changes in relation to the absolute vertical and the longitudinal body axes [3,12,19,29,30]. 4) There are no postural dynamics and stability challenges in the supine position as opposed to the constant pendulum sway in the standing one, which alter postural muscles activation. Based on this, we speculate that the influence of focusing the attention and awareness on the symmetrical alignment, along with total integration of the sensory information, enables better postural symmetry perception in standing positions.

In conclusion, our study demonstrates that both mechanical (gravitational) and perceptional factors influence body symmetry. Varying between supine and upright position impacts the gravitational forces on body parts thus leading to greater upper trunk symmetry in supine, and greater upper limb and neck symmetry in upright posture. The effect of attention and awareness on the perception of postural symmetry of the upper body (head, trunk, upper limb) leads to greater symmetrical alignment while in standing positions. Yet, more studies are needed in order to explore the influence of body awareness and body position on symmetrical alignment.

4.3. Study limitation

Although the supine position is a common every day position, there is very little knowledge about the effect of supine position on the alignment of body segments. Since our study is the first to measure anterior alignment in the supine position compared to the standing position using the photogrammetric method, we did not find values for comparison in the current literature. Future study is essential in order to increase our understanding on body alignment in supine positions. Moreover, although the photogrammetric method is considered harmless when repeated, easy to use and cost effective, it is not as accurate as radiographic measurements.

4.4. Clinical significance

We have shown that both mechanical and perceptual factors influence body symmetry. This might be used in the clinic to improve symmetry. Supine position demonstrates greater thorax symmetry compare with standing, while upright standing demonstrates greater neck and shoulder symmetry compare with supine. Enhancing body awareness and attention towards symmetrical posture (see supplementary material for specific instructions) might be integrated into the treatment of patients with altered symmetry, in order to improve postural symmetry.

Conflict of interest statement

No conflict of interest to declare.

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Authorship

AS, EB, and CGP were responsible for the study concept and design. AS and EB performed the testing. AS performed the data analysis and drafted the manuscript. EB and CGP provided critical revision of the manuscript for important intellectual content. All authors reviewed the content critically and approved the final version for publication.

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