What is Posture? A Review of the Literature in Search of a Definition

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Abstract

As a new science, posture suffers from a lack of definitions, which can often lead to misunderstandings. Looking up the definition of posture in the Oxford Dictionary one finds: "a position of a person's body when standing or sitting." This is a fair explanation for a dictionary but is unscientific in as far as it provides no inkling about the mechanisms underlying posture. Scientists have adopted similarly vague definitions for posture. Evidence shows that posture is linked to both postural control and gait and consequently to their respective neural mechanisms. Muscles and fascia are important elements in maintaining posture while joint positions also seem to influence it; a subluxation complex could be considered a local postural deviation. Additionally, emotions appear to alter posture and vice-a-versa.

In conclusion, posture can be defined as the outcome of the overall position of the joints adopted to balance the skeletal segments against gravity in a given position, serving as a basis for movement and non-verbal communication, maintained by the connective tissue and muscles under the control of the nervous system.

Defining "good" posture is hard because of the structural differences across genders and races. However, drawing on currently available knowledge it can be inferred that good posture maintains the symmetry of the body and allows the joints to be in a position that subjects them to less joint stress and muscle activity, facilitating body physiology towards more positive emotions.

Keywords: Posture; Literature; Definition

Introduction

As a relatively new science, posture suffers from a lack of clear definitions, which can often lead to misunderstandings. This situation differs from that of the science of muscle strengthening, for example, which has clear definitions and well elucidated physiology.

As stated by McGill [1], there is a general negligence of the complexity of the many systems and interactions related to posture. Looking up the definition of posture in the Oxford Dictionary [2] one finds: "a position of a person's body when standing or sitting." This is a fair explanation for a dictionary but is unscientific in as far as it gives no inkling about the mechanisms underlying posture. The problem is exacerbated when scientists adopt the similarly vague definitions found in dictionaries: "posture is defined as the alignment or orientation of body segments while maintaining an upright position" [3]; "posture is the mechanical relationship of the parts of the body to each other" [4]; "the human posture is the kinematic relationship between the joints at a given time" [5]; "human posture refers to the static disposition of limbs and body parts"[6]; "posture refers to the alignment and maintenance of body segments in certain positions" [7]. Further adding to its complexity, there is a common misconception over the relationship between posture and postural control [8]. On the other hand, considering the fact that postural control is an important part of posture as a system, Myers [9] affirmed that posture, meaning standing or sitting still, does not exist because humans are never truly static/stationary.

What is Posture? A Review of the Literature in Search of a Definition

112

Thus, given the importance of posture to human health [10], the aim of this review was to provide a deeper understanding of the latest knowledge on the neurology and biomechanics of posture and postural control. It is important to highlight that it is not the objective of this review to search for scientific proofs of new treatments or forms of assessment. The sole purpose was to identify the different relationships between posture and other scientific areas to better understand and formulate a definition of posture based on evidence requiring further validation in future articles before being clinically applied.

Methods

Outline of Search Strategy

A comprehensive search of the clinical research available was carried out. Systematic searches were conducted on the Pubmed database for publications from 2008 to date. Relevant articles found in the references of the studies retrieved were also considered.

Search Terms

The basic search terms for posture were "Posture" OR "Postural". Other terms used and crossed with the previous two were: balance; postural control; equilibrium; gait; muscle; muscular chains; biomechanics; fascia; connective tissue; subluxation; joint; temporomandibular; spine; hip; pelvis; knee; foot; shoulder; gender; race; emotions.

Selection Criteria

Given the broad spectrum of this search, all articles shedding light on the mechanisms and relationships of posture were selected. All clinical studies, including controlled trials, uncontrolled studies, observational studies and case studies were identified. Demographic studies and assessment studies were also selected. Attempts were made to locate relevant qualitative studies.

No language restrictions were imposed on the search and filtering stage, and translations were obtained for any potentially relevant studies in languages other than English.

Many articles were excluded on the basis of their title alone. For example, "Postural tachycardia syndrome (POTS)" was clearly not relevant to this review. The second filtering process was performed based on the abstract while the final stage entailed reading the whole article.

Results

Searches of the databases yielded a total of 4349 citations for initial screening, 229 of which were used in this article.

Discussion

Posture and Balance

Balance is by far the most studied component of posture. To deal with gravity, the human body has an intricate system to maintain an upright position, which shapes the muscles and governs tonus. The main components involved in postural control are: the vestibular system, vision and somatosensory system [11].

While posture still lacks a convincing definition, Pollock., *et al*. [12] provided the corner stone for the study of postural control in their explanatory article entitled "What is balance?". The authors defined some related terms as follows:

- Balance – according to the third law of Newton [13] this is the state of an object or body when the resultant force acting upon it equals zero.

What is Posture? A Review of the Literature in Search of a Definition

113

- Human balance refers to the ability of not falling over

- Centre of gravity (CoG) is the exact point through which the vector of the body´s weight passes.

- Base of support (BoS) is the area enclosed by all points of contact with the support surface.

- Postural control is the act of maintaining, achieving or restoring a state of balance during a given posture or activity.

Thus, postural control is associated with three classes of human activity: the maintenance of posture; some voluntary movements such as gait; and the reaction to an external disturbance to balance [12,14,15].

How balance shapes posture

Unlike quadrupeds, the human upright stance is an inherently unstable position [16]. As seen above, the main function of postural control is to maintain balance. Balance is attained when the CoG lies within the BoS. When the CoG is outside the BoS the body needs to produce a stronger reaction to bring the CoG back within the BoS else a fall will result.

Thus, to have good balance or good postural control is not the same as having good posture [10]. Imagine four blocks of the same size stacked one on top of the other. If they are arranged perfectly the CoG will be dead center of the BoS. Now imagine the same blocks not perfectly stacked or very poorly stacked. Despite this misalignment, the blocks remain linked and stabilized through lines working rather like ligaments, thereby maintaining balance. The body works in exactly the same way. If a body segment deviates from its natural position, another segment must deviate in the opposite direction to maintain equilibrium [10]. The body sacrifices alignment in order to preserve the upright position, countering the forces of gravity.

A good example of this compensation is the use of high heels. Constant use of stilettos may lead to shortening of the gastrocnemius and soleus. The action of the triceps surae on the feet is the plantar flexion. Severe shortening will give rise to an equinus foot, a condition normally seen in neurological patients. On the other hand, in subjects with no neurological impairments, barefoot in a closed kinetic chain, fully supported by the ground, the plantar flexion movement will incline the tibia backwards, shifting the CoG outside the BoS. To avoid falling, the body needs to bring one or more segments forward. Compensatory responses include knee hyperextension; pelvic anteversion with hyperlordosis; shoulder projection forwards; and/or head projection forwards.

This might explain why some studies seeking to correct posture utilizing the classical approach of stretching the shortened agonist and strengthening the weak antagonist (SSASWA) have failed to obtain positive results [17-22]. For the example shown in Figure 3, attempts to correct the forward-projected shoulder by pectoralis major stretching and rhomboid strengthening may prove unsuccessful because the most important muscle to be treated is the triceps surae. Without a return to normal fiber length in this muscle, the body must still project a segment forward in order to compensate for the backward projection of the tibia and prevent a fall.

Relationship between posture and gait

Some postural deviations can predict gait deficits. In fact, since posture is underpinned by postural control and center of mass (CoM), and gait equilibrium is in turn dependent on CoM, it follows that posture and gait are related [23]. Consequently, it is likely that most of the neurological and biomechanical factors affecting one also affect the other.

Foot posture is the most studied factor in the posture-gait relationship [24]. The medial longitudinal arch is crucial for shock absorbance and energy transfer during gait [25,26]. This role depends on the shape of the foot [27], bony structure [28], ligamentous stability [29,30], and muscular fatigue [31]. Other factors influencing the formation of the medial longitudinal arch are race [32], footwear [33,34], age, and gender [35]. High-arched and low-arched feet seem to be a risk factor for related lesions [36-43].

What is Posture? A Review of the Literature in Search of a Definition

114

An interesting study conducted by Levinger., *et al.* [43] employed radiography to measure foot posture and a three-dimensional motion analysis system incorporating a multi-segment foot model to measure gait kinematics. The authors investigated the differences in foot motion between people with normal and flat-arched feet and found that participants with flat-arched feet demonstrated greater peak forefoot plantar-flexion, forefoot abduction, and rear foot internal rotation. Additionally, participants with flat-arched feet demonstrated decreased peak forefoot adduction and a trend towards increased rear foot eversion.

Murley., *et al*. [44] approached the same problem from a different perspective. The authors studied the relationship between foot posture and muscle contraction measured by electromyography during gait. They found that, during the contact phase, the flat-arched group had greater activity of the tibialis anterior and lower activity of the peroneus longus. During midstance or propulsion, the flat-arched group displayed higher activity of the tibialis posterior and lower activity of peroneus longus.

Since the trunk is important in the maintenance of body balance [45], the presence of spinal deformity alters the CoM during gait, leading to the development of a pathological gait pattern [23].

Gait pattern is symmetrical in healthy populations [46-49]. By contrast, marked differences can be found between affected and unaffected limbs in pathological gait [50,51]. Scoliosis is a good example of postural asymmetry. According to postural findings, gait patterns of patients with scoliosis display some differences in symmetry compared to non-scoliotic subjects. These differences can include decreased step length [52-54] and reduced range of motion (ROM) in the upper and lower extremities (LE) [52]. Another study showed asymmetry in trunk rotation on the transverse plane. During walking, the trunk rotated asymmetrically to the line of progression, showing minimum torsion at right heel contact and maximum torsion at left heel contact, consequently producing symmetry in ground reaction force (GRF) of free rotational moment around the vertical axis [55]. In GRF studies, patients with scoliosis showed asymmetrical gait in the vertical [56], anterior–posterior [57], and medial–lateral [58] directions. Yang., *et al*. [23] found asymmetrical gait in the frontal and transverse planes of the scoliotic group compared to the control group. In their GRF data, the same authors found that the scoliosis group demonstrated asymmetrical gait in the medial–lateral direction.

Some studies have investigated other trunk morphologies that affect gait. For example, trunk inclination seems to affect gait [45,59,60]. A forward or backward inclination is maintained at gait initiation [61] and during locomotion [62]. A backward thorax inclination showed less thorax-to-pelvis motion, less motion in flexion/ extension and in lateral bending, and during push-off whereas backward inclination had more shoulder-to-thorax motion [63].

Muscular biodynamic and Posture

Muscles are the motor system for movement and their tonus also maintains posture. Some biomechanical models challenge the SSAS-WA model.

The first involves muscle synergies. A muscle synergy is a vector specifying a pattern of relative levels of muscle activation [64,65]. Synergies are also the building blocks from which complex muscle activation patterns are constructed [66-71]. The nervous system appears to use flexible combinations of only a few muscle synergies to produce a wide range of motor behaviors [66-71]. For example, muscle synergies specific to walking are similar to the single limb stance [72]. The activation of each muscle synergy is presumed to be modulated by a single neural command signal [73]. Biomechanical models based on anatomy are crucial for understanding muscle synergy function [73]. Because of these anatomical interactions between musculoskeletal elements the function of a muscle or muscle synergy cannot be understood in isolation [73]. Bearing in mind that all muscles accelerate joints but do not cross them, it is clear that both proximal and distal muscles are coactivated in order to produce stable task function [73-77].

For postural control of standing, only a small set of muscle synergies coactivates muscles along the limbs and trunk [78]. Their activity responds to specific directions of center-of-mass (CoM) motion [64,68,69,79].

What is Posture? A Review of the Literature in Search of a Definition

115

Some muscle synergies seem to be innate while others are learned. Rudimentary postural responses start at 4-5 months of age in humans [80]. On the other hand, intersubject variations in muscle synergy patterns and in number of muscle synergies indicate that muscle synergies can be created according to necessity [73]. Thus, the morphology and experience of each individual interact with each other in unique ways over time [81] producing a distinct set of muscle synergy patterns. Moreover, muscle synergies themselves may also change [82].

The second biomechanical model is based on muscle chains or myofascial chains. Françoise Mézières was the first to refer to muscle chains [83,84]. She discovered this theory and its influence on posture while treating a patient who presented with severe kyphosis complaining of being unable to raise her arms. Strengthening and stretching proved ineffective because of severe rigidity. Laying the patient down in the supine position and pressing downward on the forward abducted shoulder produced major hyperlordosis. However, when in a standing position, the patient displayed only kyphosis. Bringing the knees toward the chest resolved the lordosis problem, but the thoracic hyperlordosis moved up to the neck in this position. From this patient, Mézières started to understand that shortening of one or more of the back muscles produced functional shortening in most of the posterior chain [85]. In order to deal with this postural problem, she simultaneously stretched all the muscles belonging to a group she called muscle chains [83]. Interestingly, these chains may in fact be related to both muscle synergies and postural control, with the latter constituting the third model. All three models hold that one muscle can alter biomechanics distally. Thus, local treatment may be ineffective for treating postural problems. In fact, the muscle chains model has proven the most successful of these treatment approaches [86-92] than SSASWA [17-22].

Fascia, Connective Tissue and Postural Globality

According to Findley and DeFilippis [93], fascia shortens and thickens as the body uses postural compensatory strategies, which in turn can complicate the architectural integrity of the fascia itself. Fascia refers to sheets of dense irregular connective tissue in the human body: aponeuroses, joint capsules, or muscular envelopes such as the endomysium, perimysium and epimysium [94-96] and extends as tendons, Sharpey's fibers, and periosteum. It also forms the retinacula when it thickens transversally across bones to prevent tendons from expanding out of place during muscle activity; an example can be found in the carpal tunnel [96]. Ligaments and tendons can be considered as local thickenings of fascial sheets, adapting to increased local tension with a denser and more parallel fiber arrangement [97]. Fascia is organized in a network that surrounds, supports, suspends, protects and connects muscles, bones and viscera [98]. In fact, fascia creates continuity, being found in and around all cells in the body [99], conferring shape, form, stability, and support to the body, distributing forces applied at one point to be spread throughout and absorbed by the entire body [93].

Fascia is essential in the postures and patterns of human movement [95]. Concomitant with fascial impairments, there are frequently alignment problems, which may lead to biomechanically inefficient function [100]. This special tissue plays an important role in musculoskeletal dynamics. For example, stiffness of the plantar fascia contributes to stability of the foot [101]; the lumbar fascia limits spinal mobility [102]; and tension transmission across the epimysium contributes to muscle force [103, 104].

It seems that fascia reorganizes along the lines of biomechanical tension at molecular [105,106] and macroscopic levels [107]. Myers [108] found an anatomical relationship following tensile myofascial bands comprising a single continuous structure. Curiously, the myofascial lines proposed by Myers [108] bear many similarities to muscle chains [84,109-113]. Thus, the repercussion of a fascial restriction may create body-wide stress on any structures enveloped by fascia [114].

Besides this passive contribution to biomechanical behavior, fascia may be able to spontaneously adjust stiffness within a timeframe ranging from minutes to hours, being a more active contributor to musculoskeletal dynamics [94,97]. Evidence supporting this lies in the presence of contractile cells in fascia. Fibroblasts, chondroblasts and osteoblasts have an innate capacity to express the gene for a-smooth muscle actin (ASMA) and to display contractile behavior [115]. Its expression can be triggered by increased mechanical stimulation, for

example [94,97]. Cells containing ASMA stress fibers include contractile smooth muscle cells or a contractile phenotype of fibroblasts with smooth muscle-like features, now known as myofibroblasts [116]. These findings lend support to previous research such as the study conducted by Garfin., *et al*. [103]. The authors found that surgically releasing the fascia via a small incision in the epimysium of a dog's hindlimbs resulted in approximately 15% reduction in force production and a 50% decrease in the intracompartmental pressure developed during muscle contraction.

Joints, Subluxation and Postural Deviations

Manipulative therapies, such as osteopathy and chiropractic recognize the impact of joint alignment on the nervous system [117]. The main unit of alignment disturbance is called subluxation. This same term is also used to refer to altered spinal positions [118]. From literature on the firing of mechanoreceptors and proprioceptors in the discs [119, 120], spinal ligaments [121], spinal muscles [122] and facet capsular ligaments [123-125], it has been established that vertebral displacements are associated with asymmetrical deformations of these tissues and their piezoelectric receptors. Panjabi., *et al*. [126] have shown that the spinal ligaments are deformed in postural movements. Spinal cord research [127-129] has long established that abnormal postural rotations and translations cause spinal cord tethering [130-132] and reduction of spinal cord blood supplies [133,134]. Thus, altered posture is certainly related to subluxation [118,135].

Troyanovich., *et al*. [136] defend that spinal manipulation alone cannot solve postural problems. However, adjustment of a subluxation forms part of the therapy, used in conjunction with active exercises and stretches, resting spinal blocking procedures, extension traction and ergonomic education. While manipulation and mobilization techniques can enhance the healing process of musculoskeletal soft tissue lesions, their physiological benefits may not last long if the rehabilitation program does not include some form of neuromuscular re-education or behavioral and ergonomic modification in order to remedy "global subluxations" [137,138]. Global subluxations are defined as abnormal rotations and translations of the skull, thorax, spine, pelvis and limbs which are present in the upright static stance of an individual and may be associated with, or are a primary cause of, many neuromusculoskeletal dysfunction or syndromes [136]. Indeed, some evidence suggests that the coupling patterns seen on radiographs (i.e., relative misalignments between adjacent vertebrae) are the result of global postural displacements or positions [118,139-141].

Joint manipulation and mobilization has also been suggested by the North American Spine Society's Ad Hoc Committee on Diagnostic and Therapeutic Procedures for postural deviations and spinal dysfunction [142]. Besides joint adjustment, massage and exercises to improve strength and flexibility were also recommended. Some studies have successfully changed posture using different manipulative methods [143-146].

Postural faults are also associated with increased muscle tonus [147]. Muscles with a firm texture, which co-occur with postural alterations, have different electromyographic (EMG) characteristics to muscles with normal texture [148-150]. Unlike in normal muscle, spontaneous EMG activity was either present or inducible in high tonus muscle [151,152]. Also, the reflex erector spinae activity evoked by pressure placed against paraspinal tissues varied between subjects and between vertebral segments [150-153]. According to the authors, these patterns suggest that α motoneurons can be held in a facilitated state as a result of sensory bombardment from segmentally-related paraspinal structures. Motor reflex thresholds also correlated with pain thresholds, further suggesting that some sensory pathways were also sensitized or facilitated in the abnormal segment [150]. On the other hand, in their EMG study, DeVocht., *et al*. [154] found that manipulation induced a virtually immediate change, usually a reduction, in resting EMG levels among patients with tight paraspinal muscle bundles. This effect is helpful in managing the increased tonus associated with postural alterations. Supporting these theoretical data, more recent clinical trials have successfully utilized manipulations to improve posture [155, 156] and balance [157,158].

Good and Bad posture and race and gender effects

In 1967, Kendall., *et al*. [159] described ideal posture as having no deviations, using a plumb line as a parameter. To verify the symmetry, a bisection can be made through the following points: glabella, frenulum, episternal notch, xiphoid process, symphysis pubis, and a

What is Posture? A Review of the Literature in Search of a Definition

117

point midway between the medial malleoli of the ankle joints [160-163]. From the side view, the perfect posture should be aligned slightly posterior to the apex of the coronal suture, external auditory canal, bodies of most cervical vertebrae, shoulder joint, lumbar vertebral bodies, slightly posterior to the axis of the hip joint, slightly anterior to the axis of the knee joint, and slightly anterior to the lateral malleolus [159]. Other authors may describe this ideal lateral posture with some minor differences [160-163]: the plumb line must pass through the external auditory meatus, the odontoid process, a point just anterior to the acromioclavicular joints, slightly posterior to the center of the knee and through the lateral malleoli and talus of the ankle joints. Additionally, there must be some lordosis in the cervical, kyphosis in the thoracic, and lordosis in the lumbar spines [136].

However, there are several issues with these descriptions of a perfect posture. Myers [9] reminds that humans are never static. Thus, this concept of still posture does not truly exist. Studying balance reveals a body sway while in a standing position. This means that even someone with a "perfect" posture will not match all of the above markers, all the time. However, it does serve to provide an approximate indicator.

The second problem centers on race and gender. There are structural differences between men and women, and among people of different ethnicities. The clearest evidence of such structural differences in gender can be seen in the pelvis. Human bipedal gait affects the hip differently from the other quadruped mammals. The pelvis is vital to both locomotion and childbirth [164]. The female pelvis has evolved to its maximum width for gestation and childbirth - a wider pelvis would render women unable to walk. In contrast, the human male pelvis is not constrained by the need to give birth and is therefore optimized for bipedal locomotion [164]. Thus, the female pelvis is larger, broader, with a larger inlet and oval in shape, while the male pelvis is taller, narrower, with a further projected promontory, and is more compact [165]. The iliac crests are higher and more pronounced in males [164] while the male sacrum is long, narrow, straighter, and has a pronounced sacral promontory compared to females [164]. Thus, the sacrum and the pelvic ring of the female are wider and more circular, facilitating the passage of the newborn. This causes the acetabula to be wider apart and face more anteriorly [164,166]. Consequently, when women walk the leg must swing forward and inward, from where the pivoting head of the femur moves the leg back on another plane. In men, the leg can move forwards and backwards along a single plane [164]. A wider pelvis implies a different angle with the femur, leading to a tendency for genu valgus. As a consequence, females have a greater tendency of presenting a flat foot [167].

Again, there is evidence that posture is similar to gait with regard to gender differences. Apart from general differences in gait characteristics such as cadence and stride length [168], gender specific skeletal motion was found, such as an increased pelvic obliquity in females [169-172]. Some authors have studied gender differences in knee and hip mechanics during running [173-176]. A common finding among these authors was that female runners demonstrate greater hip adduction and internal rotation, as well as greater valgus knee throughout the stance phase [173-175,177].

Pelvic tilt also appears to differ. A cadaveric study identified significantly more pronounced retroversion signs in the pelvis of males than females [178]. Flat foot, genu valgus, pelvic anteversion and lumbar lordosis are part of the same postural pattern [167] and more common in women due to bone characteristics.

Some of these differences occur not only between genders but also between races. For example, Lavy., *et al*. [179] analyzed 99 pelvis X-rays and concluded that, besides women´s hips being more dysplastic then mens´, Japanese hips were more dysplastic than British hips, which were in turn more dysplastic than Malawian hips. Handa., *et al*. [180], studying 104 resonance magnetic images of primiparous women, concluded that white women have a wider pelvic inlet, wider outlet, and shallower anteroposterior outlet than African-American women.

There are scant studies on gender or race differences in the spine. However, where differences in pelvic size and tilt exist, there are likely differences in spine curvature. One noteworthy difference concerns thoracic spine diameters, which were shown to decrease with

What is Posture? A Review of the Literature in Search of a Definition

118

increasing age in women, yet increase with advancing age in men [181]. Another difference involves trunk kinematics in normal gait [182]. Female trunks were 5 degrees more extended during walking than male trunks. According to the authors, this disparity seems to be related to increased lordosis. If confirmed, this is in accordance with the postural patterns of Bricot [167], which describe pelvic anterior tilt with increased lumbar curvature.

For the temporomandibular joint (TMJ), men appear to have fewer dysfunction symptoms [183-185]. Epidemiologic data support the fact that women are at greater risk for TMJ dysfunction [186-188]. Moreover, women experience greater inflammation, facial pain, and tenderness in the jaw muscle and temporomandibular joint than men [189,190]. Some evidence suggests that increased inflammatory response can lead to loss of articular cartilage (Pettipher., *et al*. 1986 189) and joint disk displacement [192]. One study suggests this may occur because of a polymorphism in the estrogen receptor [188]. However, another study affirms that women tend to have greater retrognathia [193], perhaps explaining the greater incidence of TMJ dysfunction. Curiously, retrognathia may be associated with anterior pelvic tilt [167].

Another interesting study assessed 1,691 subjects for foot disorders/types, comparing African Americans with Caucasians. Compared to Caucasians, African Americans were almost 3 times more likely to have pes planus and nearly 5 times less likely to have Tailor's bunions or pes cavus. Also, African Americans had more frequent hallux valgus, hammer toes, and overlapping toes [194]. Nielsen., et al. [24] found that dynamic navicular drop was influenced by foot length and gender. Male subjects had a 0.40 mm increase in drop for every 10 mm increase in foot length, while female subjects had a 0.31 mm increase for every 10 mm increase in foot length.

Knee differences are also found. Some studies reported that the female knee has a less pronounced anterior femoral condyle height than the male knee [195-197]. There are also significant differences in knee morphology between races. Chinese for instance, have a greater tendency for valgus knee than Caucasians [198]. The authors proposed this may explain the higher prevalence of lateral tibio-femoral osteoarthritis in Chinese.

Returning to the "good posture" discussion: a clearer definition of a healthy posture was written by Kappler [199]. According to him, a good posture creates less stress on the joints, requires less muscle activity to maintain balance and, therefore, is the position of maximum effectiveness. An imbalanced posture must be compensated by changes in joint positions which, in turn, must be maintained by an increase in muscle activity, leading to injuries [199]. Postural imbalance results in increased energy consumption [199]. On the other hand, Kappler's definition does not help the clinician to any great degree. Identifying a stressed joint or increased muscle activity can take longer and be more expensive than examining posture or taking a photograph.

Emotions and non-verbal communication

The scientific study of the relationships between posture, facial expressions, gestures, emotions and nonverbal communication can be traced back to 1872 when Darwin [200] published The *Expression of the Emotions in Man and Animals*. After Darwin, a growing number of studies have been conducted investigating these relationships [201,202]. Facial expressions boast the greatest number of studies [202]. The work based on human posture has moved at a much slower pace. In 1968, Mehrabian [203] found that closed body postures (e.g., crossed arms in front of the chest and hunched shoulders) were connected with the avoidance of social conflict. More recent work on body posture has shown it to influence various aspects of psychological functioning, including arousal [204-208], somatosensation [209,210], visual detection [205,211,212] and cognition [213, 214]. Human ability to communicate emotions through posture, especially at a distance [215], has also been highlighted.

According to collaborative work by Harvard and Columbia Universities [216], adopting a high-power or low-power posture induces neuroendocrine and behavioral changes for both male and female subjects. Participants that adopted the high-power open postures experienced elevations in testosterone, decreases in cortisol, and increased feelings of power and tolerance for risk, characteristics related

What is Posture? A Review of the Literature in Search of a Definition

119

to leadership and stress management [217] Low-power closed postures on the other hand had the opposite effect. The authors discussed that adopting a posture which displays power caused positive and adaptive psychological, physiological, and behavioral changes [216].

Emotions can also affect postural control [213]. For example, Fawver., *et al.* [218] studying the influence of emotions on active control of approach-oriented posture presented their subjects with pictures representing 6 discrete categories (attack, mutilation, contamination, erotic couples, happy faces, and neutral objects). They found that following picture onset, participants leaned more anteriorly during the happy faces or attack pictures.

Bodily expression of emotions is also manifested through movements. The clearest examples are movements socially empowered with emotional meaning, such as wagging a finger, or ordinary movements charged with emotions, such as slamming a door instead closing it gently [219]. Gait is a movement that can also reveal emotions [220]. Angry walking has been described as heavy-footed with long strides, happy walking as fast paced, and sad walking as slow paced with diminished arm swing [221,222].

However, it seems that movement and gait can reveal more than this. Specific movement qualities are connected to different emotions across movement tasks. For example, sad subjects' movements have been characterized as exhibiting a collapsed upper body, low movement activity, and low movement dynamics [222], and also as very smooth, loose, slow, soft, contracted, and lacking in action [223]. Movements performed with joy are described as having elevated shoulders, backward head posture, high movement activity, expansive movement, and high movement dynamics [222], and movements with happiness as relatively jerky, loose, fast, hard, expanded, and full of action [223].

Using functional magnetic resonance images to analyze individuals while observing still photos and short movies of neutral and angry whole-body actions, Pichon., *et al.* [224] noted that anger stimuli activated the amygdala and fusiform gyrus, brain regions.

According to Gross., *et al.* [219] walking speed is fastest for joy and anger, and slowest for sadness. Other observations made by these authors were increased amplitude of hip, shoulder, elbow, pelvis and trunk motion for anger and joy compared to sadness as well as neck and thoracic flexion for sadness.

Final Considerations

An interplay of posture with many other systems was evident. It is apparent that the same system which regulates postural control also influences static posture and gait. Although differing, they are all interconnected and governed by the vestibular, visual and somatosensory systems at the neurological level.

Fascia or the connective tissue and muscles, seem to be the same. It does not matter what is working: muscular chains, muscle synergies, fascial globality or something else. The biomechanics of the body work as a whole, transmitting and absorbing kinetic energy at any point of the body, often distally to the original source of energy. Movements are not isolated but entail a chain reaction. These affect posture, balance and also gait.

Macro posture is the result of several micro postures: joint positions. If all joints are in an optimal position, overall posture will be sound. However, establishing a good sagittal posture based on anatomical position according to a plumb line is hampered by the multitude of differences in body structure across genders and races. On the other hand, the frontal plane is easier than the sagittal because body symmetry can be exploited. Kappler's definition [199] of good posture as being that which exerts minimal stress on joints and requires less muscle activity is helpful.

Clearly, bad posture is the opposite of good posture. However, the discussion on the relationship between bad posture and pain in the second part of this article is key to providing a good definition.

What is Posture? A Review of the Literature in Search of a Definition

120

It is important to differentiate some terms in a bid to prevent confusion and misunderstandings when discussing posture:

- Static posture is related to the postural analysis performed during stillness. When this analysis is done through photography there will always be a bias because of body sway.

- Static postural control is related to the analysis of balance with the subject in stillness

- Dynamic postural control is related to the analysis of balance with the subject in movement.

Conclusion

Drawing on the previous discussion, posture may thus be defined as follows

Posture is the outcome of the overall position of the joints adopted to balance the skeletal segments against gravity in a given position, serving as a basis for movement and non-verbal communication, maintained by the connective tissue and muscles under the control of the nervous system.

A good posture maintains the symmetry of the body and allows the joints to be in a position that subjects them to minimal joint stress and muscle activity, facilitating body physiology towards more positive emotions.

Bad posture will be defined in the subsequent article along with a discussion on pain.

Further studies aimed at gleaning a better understand of the differences in bone structures among genders and races, especially sagittal alignment, are vital to enhance postural assessment and treatment.

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131

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132

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133

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