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Defining Sit-Standing Postures: A Comparative Analysis of Chairless Chair Devices and Conventional Seating Ergonomics

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Abstract – This study investigates the criteria defining sit-standing postures offered by Chairless chair devices through comparative analysis. It evaluates the applicability of conventional sitting posture criteria, including balance, body segment orientation, and biomechanics, in defining unconventional postures. Findings indicate that sit-standing postures exhibit a distinct center of gravity, unique support polygons, and specific body segment geometries. Devices such as those developed by Noonee and Archelis facilitate a posture that is intermediate between sitting and standing, enhancing visual control and interaction with the workspace. This research underscores the potential ergonomic and functional benefits of these innovative seating solutions, warranting further exploration

Keywords: Sitting Posture, Sit-Standing Posture, Lumbar Load, Chairless Chair, Biomechanics.

I. INTRODUCTION

There are numerous instances where terms, situations, or concepts are used without sufficient definition. This can largely be attributed to their general familiarity, understanding, and assumed self-evidence. The term "sitting posture" in ergonomics serves as an example of this phenomenon. The need for precision has led to specialized literature successfully delineating the physical and functional framework for this posture, including Etienne Grandjean's 1976 work, which analyzes the ergonomic implications and consequences of sitting posture [1].

This article aims to identify the criteria that could underpin the definition of the posture provided by sit-standing or chairless chair devices. In the past decade, more and more concepts have been developed to assist the orthostatic posture. These projects, most notably those developed by the companies Noonee [2], are generically referred to as "Chairless Chair". Older projects, such as the chairs designed by Opsvik, developed and available on the market since the 1980s, propose a similar posture, intermediate between the orthostatic and seated posture.

To delineate the useful criteria for defining the posture, we applied the method of comparative analysis. We identified the criteria used in the delimitation of conventional sitting posture and assessed their utility for defining this unconventional posture type. For defining the sitting posture, we created a synopsis of published studies with the following selection elements identified in the keywords: sitting posture plus biomechanics, lumbar lordosis, lumbar discomfort, efficiency, characteristics. The studies highlighted characteristic elements which were subsequently transformed into defining criteria. Applying these same criteria to the unconventional posture allowed us to confirm our working hypothesis.

II. STATIC CRITERION

The criterion offered by the equilibrium condition is useful because, unlike conventional sitting postures, sit-standing postures provide a much stricter ratio between the body segment centers of gravity and the support polygon. The common center of gravity can be determined in the lateral representation plane by summing the centers of gravity of the body segments. It is expected that the common center of gravity is closer to the trunk than in conventional seating situations. This is mainly due to the angle between the thigh and the trunk.

A second particularity of the sit-standing posture is the configuration of the support polygon. In all situations, the footprint of the feet is contained within the support polygon. The posterior extension with support located behind the heel increases the surface area of the support polygon differently, depending on the distance between the heel and the additional contact point.

A third characteristic of balance in the sit-standing posture is the simultaneous accumulation of two conditions: a common center of gravity positioned at a

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higher height than in conventional seated postures, and at the same time, a more restricted support polygon. Hence, it is evident that the balance pyramid is less stable for sit-standing postures compared to conventional ones. This aspect may seem like a disadvantage at first glance, but it is important to note that the orthostatic posture is characterized by an even more precarious balance pyramid without it being an inconvenience for maintaining balance. Being an intermediate posture between standing and sitting, it retains the dynamic characteristics of the former but with the desideratum of relaxing the triple extension chain, as in the case of the latter.

III. MORPHOLOGICAL CRITERION

While the previous criterion was valuable for describing the sit-standing posture from the point of view of balance, the morphological criterion describes the spatial orientation of the body segments, which we can call the geometry of the body segments.

The first morphological characteristic of the sit-standing posture is the verticality of the trunk. Considering the skeletal volume of the thorax and pelvis, we can observe a similarity between their positions in the sit- standing posture and the orthostatic posture (Fig 1. and Fig. 2). The two skeletal volumes have almost identical orientation and inclination to those in standing: the pelvis is in anterior rotation, rotated forward, and the thorax is in posterior tilt, inclined backward. The longitudinal axes of the two skeletal volumes intersect in the abdomen area, retro-umbilical. This characteristic is found in both the orthostatic and sit-standing postures.

A second morphological characteristic is the orientation of the cephalic extremity, which, as in the case of the orthostatic posture, has the Frankfurt horizontal parallel to the ground, for the condition of balanced muscle tone.

A third morphological characteristic is derived from the analysis of the lower limb segments. The thigh is lowered below the horizontal with a variable value depending on the design of the sit-standing device.

The knee flexion angle is greater than in the conventional seated posture, its value also being determined by the design of the sit- standing device. In response to the increased angles of the hip and knee, they are compensated by a smaller dorsiflexion angle of the foot relative to the leg. This dorsiflexion angle of the ankle appears to be a limiting factor for the other two, knee and hip, due to the limited capacity of human subjects to tolerate dorsiflexion values for extended periods (weight loading, edema, advanced age) [3] [4].

Concluding the morphological criterion, we can observe that the region encompassing the pelvis, abdomen, thorax, and cervico-cephalic segment have a superimposable geometry to that of the orthostatic posture, while the lower limb segment offers a succession of alternating angles.

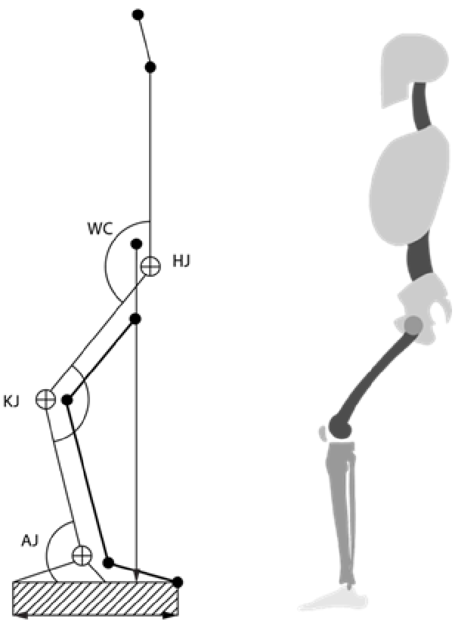

Fig. 1. Schematics of Nonee device

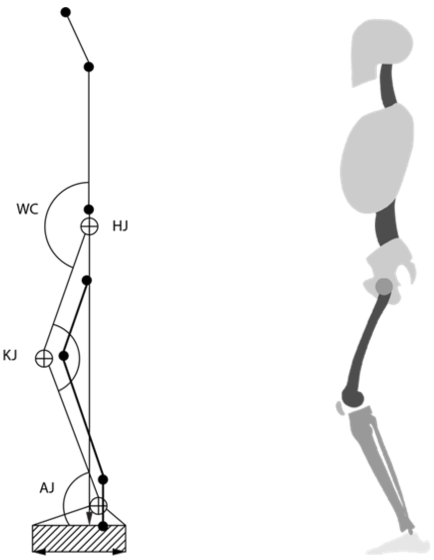

Fig. 2. Schematics of Archelis device

IV. BIOMECHANICAL CRITERION

In both conventional seated and sit-standing postures, the thorax and pelvis form a functional unit whose morphology and conformation are predictable. The thorax and pelvis respond to each other in terms of inclination, with both skeletal volumes being united by the muscle couple of spinal extensors and abdominal muscles.

The functional unit of thorax-pelvis explains why an anterior tilt of the pelvis is accompanied by a posterior tilt of the thorax. This conformation is specific to the orthostatic posture and is sought after in the design of both conventional and unconventional seating instruments. A separate discussion concerns the neutral lumbar spine [5].

This term, without excluding the tilting interplay between the thorax and pelvis, questions whether the orthostatic posture ensures a neutral spine. Regardless, the muscle couple formed between the spinal extensors and abdominals is responsible for the distinct tilting of the thorax and pelvis. In the conventional seated posture, this muscle couple is incapable of spontaneously producing the desired effects: distinct tilting of the thorax and pelvis alongside lumbar lordosis. For this reason, conventional instruments offer lumbar and thoracic support in their design concepts.

These two components represent a constant in the design of conventional seating instruments for any purpose today. The development of unconventional seating instruments, such as kneeling chairs, saddle chairs, and recently sit-standing devices, benefits from liberation from the imperative of lumbar and thoracic support.

The observation that increasing the flexion angle between the thigh and trunk brings the lumbar spine closer to values like those in orthostatic posture and neutral position continues to be a subject of interest for biomechanical explanations, structural conditioning, and the concepts of the most revolutionary sit-standing designs. The muscle couple of spinal extensors and abdominals are not the only ones involved in the biomechanics of the posture [9].

Relative to a thorax fixed to the pelvis, the cervical spine and cephalic extremity find equilibrium through the interplay of neck muscles, the anterior rectus of the head, and sternocleidomastoid muscles. The thigh clearly delineates between conventional and unconventional postures. Increasing the flexion angle between the thigh and trunk can be achieved without engaging the triple extension chain [10 - 14].

In the intermediate sit-standing position, the tonus and activation of this chain are supplemented by various support structures of the unconventional posture. In the case of kneeling chairs, there is support for the knees. In the case of saddle chairs, the inclined seat surface is combined with the horizontal plane of the floor. For sit-standing devices, we encounter blocked knee joint flexion and posterior support for the calcaneal region [6].

In kneeling chairs, saddle chairs, and sit- standing devices, there are solutions to limit ankle, knee, and hip flexion to intermediate values, between orthostatic and conventional seated postures. For devices identified on the market, Noonee and Archelis, ground support behind the heel serves to offload weight borne by the support structure. The weight of the trunk is transferred through a component collinear with the axis of the thigh and another component perpendicular to the same axis, which is borne by the device's support structure. Archelis and Noonee offer containment around the thigh in the form of an exoskeleton. [15].

The exoskeletal structure around the leg supports the weight and transmits it to the ground. The similarity between kneeling chairs, saddle chairs, and sit- standing instruments relates to the increased angle between the thigh and trunk, the transfer of trunk weight through the seat in saddle chairs, through the seat and knee support in kneeling chairs, and through the exoskeleton of the thigh and leg in sit-standing instruments. The exoskeleton of the thigh and leg has a dual role, transmitting the weight of the trunk to each other and blocking knee joint flexion at the specified value [7].

V. FUNCTIONAL CRITERION

The functionality of the seated posture differs in unconventional sit-standing instruments compared to conventional instruments. The term functionality encompasses the relationship between the trunk and upper limbs to the working area and the visual control of work areas and the ambient space [8].

By increasing the flexion angle between the thigh and trunk, the work plane approaches the trunk, especially as the trunk maintains the verticality of the orthostatic posture. This results in a more advanced position of the upper limb origin (scapulohumeral joint).

In contrast to conventional seated posture, where the trunk is often reclined on the backrest, and the visual field is determined by a retracted position of the head, sit-standing postures seem to offer several advantages. The higher and more advanced position of the head allows for much better visual control over the work areas and the depth of the visual field.

VI. PHYSICAL AND FUNCTIONAL CLEARANCE

The difference in body segment geometry generates different dimensions for conventional versus unconventional seating instruments. While the width of seating instruments is determined by the bitrochanteric and possibly bihumeral diameter for both types of seated postures, the depth dimensions differ. For conventional seating instruments, depth is much smaller than the distance between the popliteal space and buttocks (Fig. 3 and Fig. 4).

Functional clearance is also modified by reducing the clearance for the thigh and knee. On the other hand, head clearance is greater for unconventional seating instruments [16]. Changes in physical and functional clearance lead to modifications in the spatial distribution of physical volumes, functional volumes, and traffic spaces.

Thus, transitioning from a conventional seated to a vertical position requires more functional space (moving the chair back, freeing the thighs and knees from clearance limits). Using unconventional seating instruments offers another difference in traffic and interaction spaces, allowing for more efficient organization.

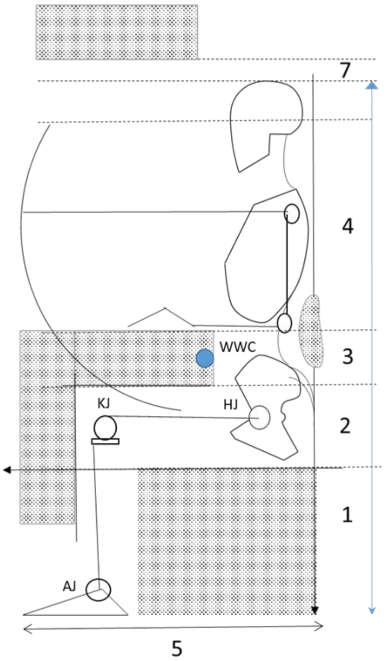

Fig. 3. Siting dimensions
1. Seat Height
2. Thigh Clearance
3. Work Surface Volume
4. Eye Level Height
5. Functional Depth
6. Functional Height
7. Head Clearance

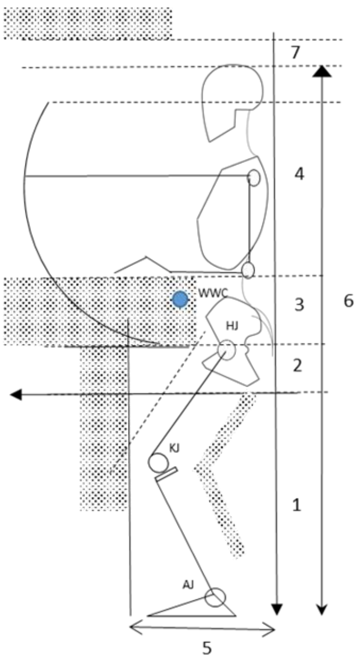

Fig. 4. Standing dimensions
1. Seat Height
2. Thigh Clearance
3. Work Surface Volume
4. Eye Level Height
5. Functional Depth
6. Functional Height
7. Head Clearance

VII. CONCLUSIONS

The utilization of the criteria is valuable for defining the unconventional sit- standing posture. This description can be independent of that of Chairless chair instruments. The importance of defining posture is underscored by the concept of human-centered design. The design solution must be a response to the morphological structure of the human body, rather than the other way around.

The sitting function should naturally align with the human body's biomechanical reality, and the design solution for sitting instruments should conceptually coincide with the structural provisions required to achieve the sitting function.

The definition of posture, as analyzed by Keegan and Grandjean, can be applied to the analysis of a new posture, which we term unconventional. In specialized literature, this posture can also be referred to by other names, as follows:

1. Declined Sitting: "Best Ways to Sit with Lower Back Pain (from an Ergonomist)," Ergonomic Trends, https://ergonomictrends.com/best-ways- to-sit-with-back-pain/, accessed 9 June 2024.
2. Balanced Sitting: "Balanced Sitting Posture on Forward Sloping Seat," A.C. Mandal, MD, http://www.acmandal.com/, accessed 9, June 2024.
3. Semi-kneeling.

Regardless of the type of seated posture, the geometry of body segments and their functional relationship to the supportive structure of the chair and the surrounding space can serve as the instrument for characterization. We consider that this analysis could be furthered by including cultural, aesthetic, and public expectation criteria regarding innovative concepts.

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