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Original Article

Design of An Ergonomic Standing Aid Device

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Abstract *- Most professions nowadays demand extended hours of standing, which contribute to discomfort and Work-Related Musculoskeletal Disorders (WMSDs). The study aims to design and develop a collapsible and adjustable leg support and standing aid to alleviate the same issues by providing ergonomic support designed based on Anthropometric measurements for different individual users. The device was designed using anthropometric data from a comprehensive study involving 1,805 Filipino manufacturing workers. Design for extremes and design for an adjustable range were incorporated in the design process, making the device suitable for a range of users from the 5th percentile female to the 95th percentile male. By featuring a multi-point support system that includes lumbar, buttocks, and shin support, the device facilitates a semi-standing "Perching" posture promoting an open hip angle of approximately 135 degrees. Biomechanical simulations demonstrated that this configuration successfully offloads up to 60% of the user's body weight from the knees and ankles. Furthermore, static load and stability simulations dictated the material selection process, ensuring the chosen material's yield strength would provide a safety factor greater than 2.0. The gadget is simple to store and move because it is foldable and portable. This study emphasizes how crucial it is to incorporate Anthropometric information into ergonomic design in order to produce viable, user-centered solutions that improve comfort and health at work.*

Keywords *- Anthropometry, Occupational Health, Prolonged Standing, Standing Aid, Work-related Musculoskeletal Disorders.*

1. Introduction

The aim of ergonomics is to provide a safe, healthy, and convenient working environment that is appropriate for the user and his/her work needs. Ergonomics, also known as Human Factors Engineering, uses a systematic body of knowledge about human interaction with the environment and tools to design systems to maximize human well-being and overall system performance.

By taking into account human capabilities and limitations, whether physical in terms of size, strength, ability, speed, or sensory capacity (vision & hearing), or psychological, ergonomics seeks to design the working environment in such a way as to be safe, comfortable, and as productive as possible [1].

One of the applications of ergonomics is in connection with the reduction of risk factors for work-related musculoskeletal disorders. Musculoskeletal disorders are some of the painful conditions that affect the muscles, tendons, and nerves in different parts of the human body, usually associated with tasks such as repetitive movements, heavy lifting, awkward postures, or holding static positions for a prolonged period of time, such as standing [2]. WMSDs can occur in the back, neck, shoulders, upper limbs, and lower limbs, characterized by pains ranging from mild to severe, painful conditions that are debilitating and require medical attention [3]. Standing for a prolonged period of time is a common work requirement among different professionals, such as industrial assembly line workers, hair stylists, salespersons, receptionists, traffic police, and security personnel. Standing for a prolonged period of time has been identified as a major occupational risk factor associated with discomfort and fatigue, which, if continued for a long time, may result in WMSDs [4]. Maintaining an upright posture demands a lot of muscular effort, especially in the lower limbs, which may result in decreased blood flow and subsequent fatigue and pain in the neck, back, and leg muscles [5].

Research by Halim et al. [6] has shown that standing for more than half of your working day will result in significant discomfort to the lower limbs due to reduced blood flow to the legs. Muscle fatigue (a known cause of pain) occurs rapidly as well. Sartika et al. [7] have shown that poor postures increase the rapidity of muscle fatigue. Notably, the time it takes to develop fatigue is relatively brief. Gregory et al. [8] report that certain calf muscles may fatigue after less than five minutes of stationary standing, whereas muscles in the lower back may tolerate this form of activity for approximately 35-60 minutes.

Further research supports these results. According to Wong et al. [9], low back pain from prolonged standing affected 65% of asymptomatic people, suggesting that the issue is common even among people who have never had any health issues. Similarly, Lafond et al. [10] discovered a link between industrial workers' low back pain and extended standing. Prolonged standing has been linked to lower back pain as well as lower extremity pain, particularly in the feet, and even in the hips and thighs when standing and sitting alternately [11].

These hazards are reflected across various high-standing occupations. The overall prevalence of WMSDs among workers in auto factories who stood for more than six hours a day was 62.75%, with the most affected areas being the lower back (18.8%), shoulders (11.2%), wrists (10.2%), and ankles (9.18%). The prevalence is even higher in the service and hospitality industries, where 81.5% of cashiers report WMSDs (with the most severe pain in the shoulders at 58.6% and lower back at 48.8%) and up to 90.6% of kitchen employees report WMSDs with extremely severe pain in the lower back (64.8%), knees (46.9%), and feet (46.1%) [12]. Additionally, studies focusing on security guards exposed to prolonged standing found that the most commonly reported areas of musculoskeletal pain are the feet (73.78%) and lower legs (23.70%).

To overcome these ergonomic issues, several solutions have been proposed, such as the use of anti-fatigue mats, adjustable workstations, and ergonomic footwear [13]. Nevertheless, these solutions may not be portable or adjustable for individual users. Recent developments in ergonomic design have highlighted the importance of developing personalized solutions that can be adjusted according to individual differences in anthropometry and occupational tasks [14].

The innovative design proposed in this study aims to fill this gap by proposing a standing aid device that is not only portable and lightweight but also fully adjustable to cater to the individual needs of each user. The standing aid device has lumbar support and buttocks support with a frame standing on the floor and linking the substructures of the buttocks support, lumbar support, and shin support, as well as foot support surfaces. The shin support consists of a shin support pad that is positioned on the knee and is supported by a height-adjustable shaft. The lower tubular shaft links the shin support to the platform. The platform is positioned on the floor and can support the standing position of the system. The anti-skid foot mat is fixed to the platform and is foldable to function as a footrest.

The design included a lumbar support pad, a feature that has been proven to significantly affect the reduction of lower back pain. Lumbar support maintains the natural curve of the spine and reduces inequality of the distribution of load throughout the lower back muscles, thereby minimizing the risks of pain [15]. The buttock and shin pads can help to reduce pressure on both the buttocks and the shins that typically experience discomfort after long periods of standing. The multiple points of contact provide a comfortable support for the body in order to prevent WMSD's and decrease the amount of strain on the muscles and joints. [16]

This device folds up and collapses, allowing for easy relocation. It fits into small spaces and is built from tough but lightweight materials, ensuring a compact footprint and ease of transport across industrial environments.

In a nutshell, the objective of this research study is to design a standing aid tool that not only addresses the ergonomic problem posed by prolonged standing but is also practical and adjustable to suit different working environments. The design would greatly improve the health condition of those workers who require extended periods of standing at their workplaces.

2. Research Method

2.1. Anthropometric Measurements

In the design of the standing aid device, the relevant anthropometric data were considered to ensure that the device is functional and comfortable to use. Anthropometric data plays a significant role in the design of ergonomic devices, especially those that require accommodating different body sizes and shapes [16]. In this study, static anthropometry was employed to determine the body dimensions in a structural position.

The anthropometric information used in this study came from Del Prado-Lu (2007). The 1,805 Filipino manufacturing workers surveyed in this study were from 31 different manufacturing industries [17]. It was the first comprehensive anthropometric survey of Filipino manufacturing workers ever conducted. It provides the needed data to develop ergonomic solutions for this population. The specific anthropometric measurements (popliteal height, hip height, hip breadth when sitting, foot length, and foot breadth) are important to design a comfortable and supportive working environment. In particular, these data will be used to design and engineer ergonomic equipment (i.e., seats) that reduce worker discomfort, improves worker comfort, and provide better working conditions. The specific anthropometric dimensions listed in Table 1 are those used to design the ergonomic standing aid device illustrated in Figure 1. These dimensions also helped to determine the height and width of the device to accommodate as many body types and sizes as possible.

Table 1. Description of body dimensions used in designing

Body Dimension	Description
Popliteal Height	Distance from the floor to the point underneath your knee where the biceps femoris muscle meets the tibia (lower leg) [17].
Hip Height	Distance from the floor to the great trochanter (the bony prominence on the superior aspect of the femur) [17].
Hip Breadth (Sitting)	Maximum horizontal distance across the hips while sitting [17].
Foot Length	The maximum distance between the most anterior (front) and posterior (rear) projecting parts of the foot [17].
Foot Breadth	Distance between the lateral and medial sides in the metatarsal region [17].

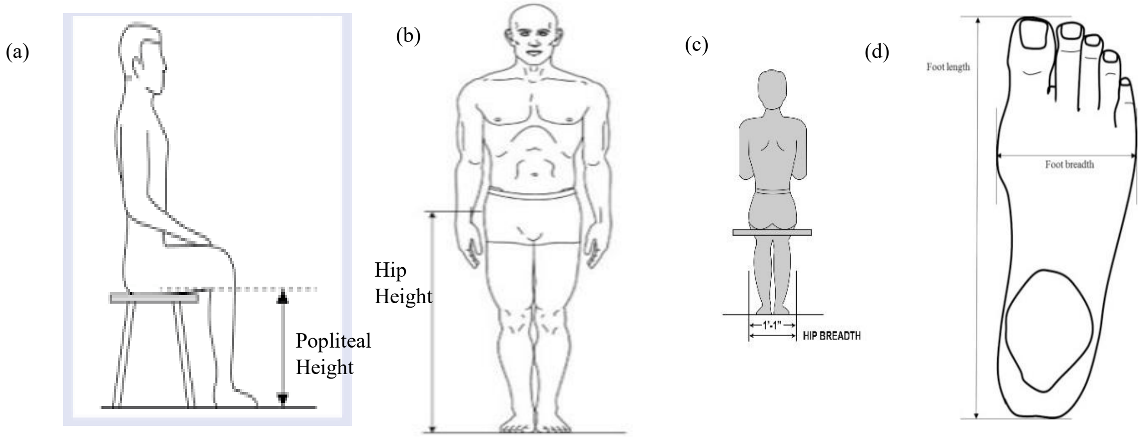

Fig. 1 Anthropometric Dimensions Required in Standing Aid Design. (a) Popliteal Height, (b) Hip Height, (c) Hip Breadth, and (d) Foot length and Foot Width.

2.2. Design Process

2.2.1. Parametric Modeling and Software Application

The conceptualization and details of the standing aid were performed using AutoCAD. The Computer-Aided Design (CAD) software is preferred in engineering and industrial design because of its high accuracy and versatility in the design of complex mechanical assemblies [18]. The use of AutoCAD software allowed the research team to create a 3D model of the standing aid, which enables the visualization of mechanisms, joint tolerances, and the relationship between the user and the device before prototyping.

To guarantee that the device would be able to withstand the target demographic safely without catastrophic failure, a static load simulation was employed with a focus on the most stressed pivot point of the device, the height-Locking Mechanism (LM-001H). The parameters for the simulation were established according to the 95th percentile male user with a weight of 90 kg. To factor in dynamic loading and the weight of heavy industrial clothing and Personal Protective Equipment (PPE), a conservative safety factor was employed, establishing a maximum design load of 110 kg.

The simulation was employed to calculate the internal shear stress on the locking pin from the bending moment (Torque) generated by the user's leaning posture. The aforementioned considerations contributed to the determination of the material, which was intended to possess a yield strength providing a safety factor in excess of 2.0 [1, 19].

A secondary simulation was also performed to assess the device's biomechanical offloading capability and base stability. A 2D free-body diagram framework was employed to simulate the axial load distribution as the user interacts with the seat at the desired 135° open hip angle. The simulation determined the percentage of body weight successfully offloaded from the lower limbs to the device.

2.2.2. Integration of Anthropometric Data

The 3D model was created based on anthropometric data from Filipino factory workers. To make sure that the device could be worn comfortably by a wide range of workers, it was designed for both the 5th percentile female and the 95th percentile male.

2.2.3. Component Dimensioning and Clearances

The standing aid was designed to accommodate each aspect of the design based on the population of users' body measurement data. The vertical adjustment mechanisms are modeled to be in direct proportion to the intended populations' popliteal and hip height, providing a smooth transition from user to user regardless of stature or size. Clearance dimension data-such as the increased width of the support platform and the length of the base foot mat-are included in the CAD modeling to accommodate the 95th percentile female hip breadths and the 95th percentile male foot lengths, plus an allowance for footwear. By incorporating these human body measurements into the mechanical geometry of the standing aid, the standing aid has been designed to meet the biomechanical requirements of the workforce that will use it.

2.2.4. Ergonomic Principles

The design of the standing aid was governed by three fundamental ergonomic principles:

Design for an Adjustable Range

To address the various statuses of the workforce, vertical adjustability is used by this device. The popliteal and hip support heights were designed to span the full height range from the 5th percentile female to the 95th percentile male.

Design for Extreme Individuals (Clearance)

For dimensions that are fixed and cannot be adjusted, the design accounts for the upper limit. The seat width (43 cm) and foot mat depth (31 cm) were dimensioned to clear the 95th percentile female hip breadth and the 95th percentile male foot length, plus a footwear allowance.

Biomechanical Offloading and Neutral Posture

The exhaustion of the lower body in any state of standing is well documented - just like conventional sitting, prolonged standing can strain the lower back. To address this, the standing aid was designed to enable a semi-standing "Perching" position. By encouraging a greater, 135-degree angle in the hips, the device supports maintenance of the natural curve of the spine. More importantly, this posture helps shift as much as 60% of the user's body weight off other vulnerable joints-specifically the knees and ankles.

2.3. Data Analysis

Mean, standard deviation, and percentiles for each relevant anthropometric variable were adopted from a study by Del Prado, wherein she gathered anthropometric measurements of Filipino manufacturing workers. These Anthropometric data were then used to create a 3D model of the standing aid device using AutoCAD. This approach aligns with best practices in ergonomic design, which typically aim to ensure products fit 95% of the population to ensure inclusivity and usability [19].

3. Results and Discussion

Data on anthropometrics were gathered from an extensive study of Del Prado-Lu, which was conducted among 1,805 Filipino manufacturing workers. The sample was composed of 53.3% women and 46.7% men, most aged under 30 years old (77%), with the majority being single (60.4%)(reflecting a young workforce). This population information is important for linking to the details of anthropometry and its application to ergonomic device design in this population [17].

3.1. Anthropometric Data and Design Principles

Table 2 shows the descriptive statistics of the anthropometric measurements: mean, 5th and 95th percentiles, and medians by sex. These parameters helped determine the dimensions of the standing aid. Two principles of design in anthropometry were used: "design for the extremes" and "design for an adjustable range". The principle of "design for extremes" takes into consideration the 95th percentile male and the 5th percentile female to ensure that a minimum range of body sizes is accounted for in design. An adjustable range provides flexibility; hence, the standing aid can be adjusted to meet the specific needs of each individual [1].

Table 3 shows the recommended dimensions for the design of the standing aid based on the 5th and 95th percentile values. The width of the buttock support was set at 43 cm, based on the 95th percentile female hip breadth. This dimension ensures that the support is wide enough to accommodate a user's hips and clothing comfortably, which is essential for user satisfaction and long-term use [20].

Foot mat width and foot mat length were established as 31 cm plus footwear allowance and 11.50 cm by using the width and length of the 95th percentile male foot, respectively. Crucial for stability and balance, which reduces fatigue from long periods of standing.

3.2. Discussion of the Design Features

Adjustable features ensure comfort while using the standing aid and prevent musculoskeletal disorders as the device is adapted to the body of the individual using it. This method of anthropometric data use in design makes it conform to the best ergonomic design practices that encourage functional and adaptable products for any user [1, 14].

Figure 2 shows how the standing aid works and depicts the isometric view of the leg support and the standing aid. The front view provides information in terms of height and width to indicate the general support surface of the device and its leg structure. The rear view shows the adjustable mechanism, which enables it to be collapsed and extended, thus making it convenient for storing and carrying. Left and side views provide side profiles of the product detailing how the legs are placed and adjusted in conjunction with the support platform. The top view displays the surface area where the user will rest his legs, stressing the ergonomic design. An ISO view gives a 3D perspective on the device, detailing how various components fit together. The collapsible and adjustable leg support and standing aid device comprises a knee pad supported by a height-adjustable hollow shaft, a lumbar support pad with a flat bar supported by a height-adjustable shaft, a foldable foot mat attached to the platform, and an inclined shaft attached to the platform. The device can also be tilted between 75° and 60°, thus providing a moderately adjustable angle of inclination as it could be set up to suit the convenience and specific desire of the user. The device is designed to collapse and be adjusted with ease. Its collapsible nature allows it to be compactly stored when not in use, making it convenient for users with limited space.

Table 2. Anthropometric measurement

Body Dimension (cm)	Male				Female			
	Mean	5th percentile	Median	95th percentile	Mean	5th percentile	Median	95th percentile
Popliteal Height	46.35	41.5	47	51	42.05	37	42	47
Hip Height	97.66	81	89	96	85.34	79	86	94
Hip Breadth, sitting	35.6	31	35	41	36.39	31	36	42.43
Foot length	25.42	23	25.5	28	22.63	20	23	25
Foot breadth	10.52	8.5	10	11.5	9.5	8	9	11

The lumbar support pad is convex-shaped, 4 inches thick, molds to satisfy every irregular angle in the user's alignment, and has a height-adjustment mechanism. The upper hollow shaft connects the buttocks and lumbar support to the shin pad. There is a locking mechanism that can be rotated and adjusted based on the preferred height of the user.

The shin support comprises a shin support pad that rests on the knee and is supported by a height-adjustable shaft. The lower tubular shaft connects the shin support to the platform and is adjustable depending on the preferred height of the user.

The platform is placed on the floor and can withstand the upright position of the system. The foot mat is attached to the platform. It is made of an anti-skidding material and an anti-fatigue mat to absorb shock and reduce fatigue to the user's feet, legs, and back. The device is made from durable, lightweight materials that ensure both stability and ease of handling. The selection of materials likely focuses on being both strong enough to support weight and light enough for portability. Table 4 lists the various parts and materials that will be used in making the leg support and standing aid device. The standing aid was designed based on the body measurements of a 95th percentile male and a 5th percentile female in order to cover a wide range of people, as supported by the ergonomic principles that aimed at making tools and equipment accessible and effective by a wide variety of users [19]. All features of adjustment, height, and width of the support are designed to minimize both discomfort and injury. Long duration of standing is blamed for a number of issues and complaints regarding health. Such concerns include feeling tired, experiencing pain in the legs, or even lower back problems [9]. The use of a standing aid reduces these risks and is especially effective for people who require them to stand for long periods.

3.3. Biomechanical and Structural Simulation Analysis

The standing aid's overall performance is evaluated from two main angles: whether it is appropriate for the workforce and whether it can safely support their weight. The anthropometric information of Filipino manufacturing workers was directly correlated with the device's ranges to ascertain the true rate of accommodation. To confirm this, a static load analysis was conducted on the most critical stress points-especially the height-locking mechanism-ensuring the materials possess enough yield strength to support a heavy, 95th percentile user without bending or breaking.

3.3.1. Simulation Parameters and Boundary Conditions

In order to ensure that the simulation results are as close to reality as possible, the testing parameters were designed with a set of constants and "worst-case" simulations in mind. Table 5 below lists the parameters. Instead of using random numbers, these parameters were carefully taken from the actual body measurements of Filipino manufacturing workers, combined with engineering constants and safety factors for industrial workplace furniture.

3.3.2. Structural Integrity & Material Selection

To ensure that the Height-Locking Mechanism (LM-001H) would not fail under pressure, a static load simulation was conducted using a worst-case scenario. The base weight was set at the 95th percentile for a male user at 90 kg. However, considering the weight of heavy work clothing or Personal Protective Equipment (PPE), the absolute maximum design load was set at 110 kg.

Vertical Gravitational Force (F_g):

The downward force exerted by the user is calculated using the standard acceleration due to gravity (g= 9.81 m/s^2):

$$F_g = m \; x \; g$$

$$F_g = 110kg \; x \; 9.81 \; m/s^2 = 1{,}079.1 \text{ N} \qquad (1)$$

Torque (τ) at the Pivot Point:

Because the user leans backward, the vertical load is applied at a distance from the locking mechanism, creating a bending moment (torque):

$$\tau = F_g \; x \; d$$

$$\tau = 1079.1 \; N \; x \; 0.25 \; m = 269.78 \; Nm \qquad (2)$$

Shear Force (F_{shear}) on the Locking Pin:

The torque is resisted by the internal locking pin. The shear force trying to slice through the pin is calculated by dividing the torque by the pin's radial distance from the pivot center:

$$F_{shear} = \frac{\tau}{Internal\ radius} \tag{3}$$

$$F_{shear} = \frac{269.78\ Nm}{0.02\ m} = 13{,}489\ N$$

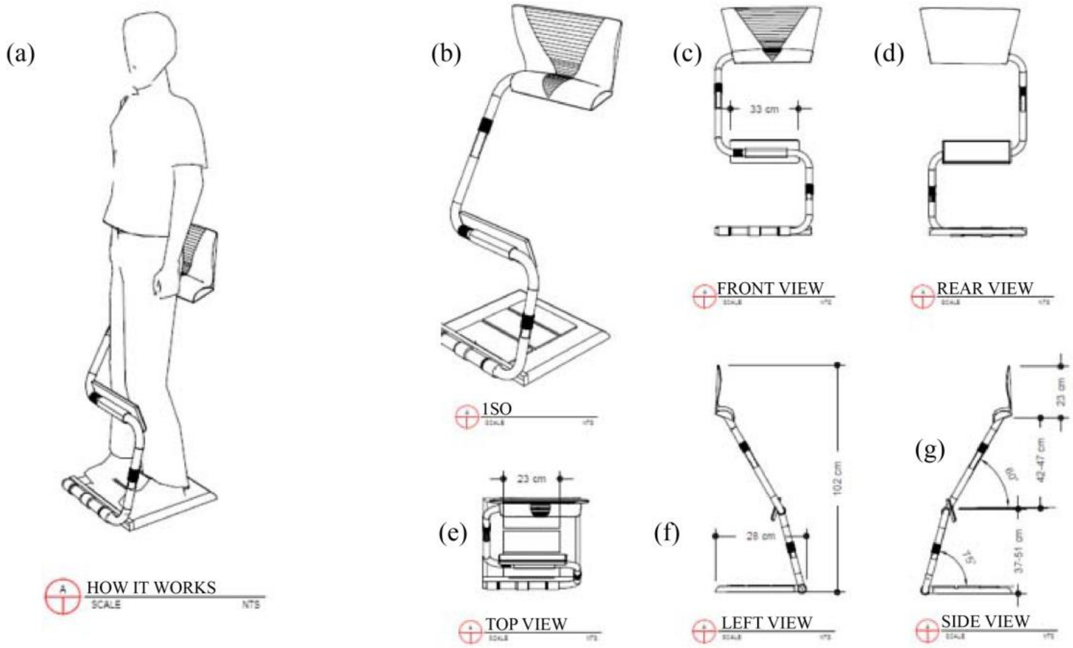

Fig. 2(a) Representation of the standing aid, (b) Isometric View, (c) Front View, (d) Rear View, (e) Top View, (f) Left View, and (g) Side View.

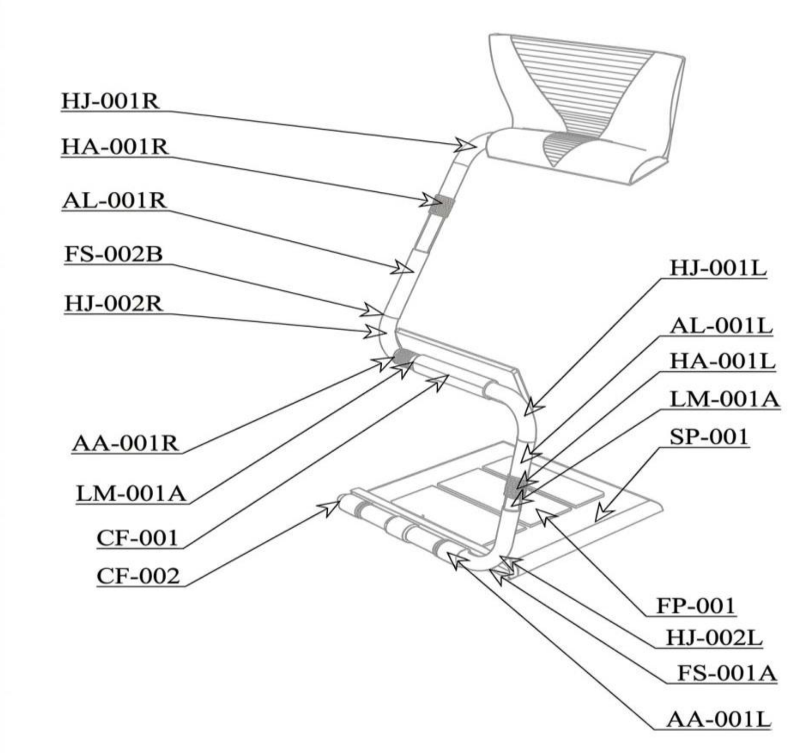

Fig. 3 Isometric View with Part Code

Table 3. Recommended Dimensions for the Design of the Standing Aid

Standing Aid Features	Anthropometric Data	Dimension (cm)	Criteria Determinant
Height of standing aid	Hip height	79-97.66	5th (female) -95th (male) percentile of hip height
Height of buttocks supported by the floor	Popliteal Height	37-51	5th (female) -95th (male) percentile of popliteal height
Width of Buttock Support	Hip Breadth, sitting	43	95th (female) percentile of hip breadth
Width of the foot mat	Foot length	31	95th (male) percentile of foot length + footwear allowance
Length of Foot mat	Foot breadth	11.5	95th (male) percentile of foot breadth

Shear stress (σ_{shear}) on the pin:

First, the cross-sectional area (A) of the 8 mm pin is calculated:

$$A = \pi \; x \; r^2$$

$$A = \pi \; x \; (0.004m)^2 \approx 5.03 \; x \; 10^{-5} m^2 \qquad (4)$$

Next, the shear stress is determined by dividing the shear force by the cross-sectional area:

$$\sigma_{shear} = \frac{F_{shear}}{A}$$

$$\sigma_{shear} = \frac{13{,}489 \; N}{5.03 \; x \; 10^{-5} m^2}$$

$$\sigma_{shear} \approx 268{,}170{,}974 \; Pa \approx 268 \; Mpa \qquad (5)$$

Calculations revealed that the locking mechanism would be subjected to approximately 268 MPa of shear stress when subjected to maximum load. Due to the high force involved, the use of stainless steel was particularly considered for all the locking parts to avoid any possibility of failure.

Since structural stainless steel has a baseline yield strength exceeding 215 MPa, and heat-treated versions easily exceeding 500 MPa, this upgrade ensures that the height locks will not bend or deform.

3.3.3. Anthropometric Accommodation Analysis

To avoid any uncomfortable pressure points on the thighs, the seat width was increased to a minimum of 43 cm, which is well clear of the 95th percentile female hip breadth of 42.43 cm. At the bottom of the design, the Foot Mat (FP-001) was increased in depth to 31 cm. Given that the 95th percentile male has a barefoot length of 28 cm, the additional 3 cm is simply a necessary and useful buffer zone for large industrial work boots. Ultimately, these specific design decisions ensure that the equipment is stable, slip-resistant, and accommodating for the absolute extremes of the workforce.

3.3.4. Driving Force & Stability Simulation

A stability simulation was conducted to determine the risk of the device sliding backward (“kick-out”) when a user leans against it. Using a standard leaning angle (θ) of 15° and a 95th percentile male load, the horizontal driving Force (F_x) was calculated:

$$F_x = F_y \; x \tan(15^o)$$

$$F_x = 530 \; N \; x \; 0.268 \approx 142 \; N \qquad (6)$$

This force is countered by the friction generated by the Rubber or TPE base pads (FP-001). Assuming a coefficient of friction (μ) of 0.6 for rubber on industrial flooring, the resisting friction force (F_f) is

$$F_f = F_y \; x \; \mu$$

$$F_f = 530 \; N \; x \; 0.6 \; \approx 318 \; N \qquad (7)$$

Because the resisting friction (318 N) easily overpowers the horizontal driving force (142 N), the standing aid achieves a safety factor greater than 2.0 against sliding. This means the base generates more than enough traction to stay firmly in place, ensuring the equipment will not accidentally slip away from a worker during a normal shift.

3.3.5. Biomechanical Efficacy

The last simulation was about the effectiveness of the design in aligning the spine and relieving the weight of the body. Figure 4 shows a 2D Free-Body Diagram (FBD) of the user positioned at rest at the desired 135° open hip position. The group was able to identify the exact position where the stress is directed.

As seen in Figure 4, the free-body diagram shows the distribution of the quasi-static load, which effectively indicates the direction of the forces as they are transferred from the user to the device’s lumbar and knee supports.

The weight of the upper torso (W_t) is applied at the center of gravity and is partially counteracted by the lumbar reaction force (N_lumbar), thus reducing the compressive force on the lumbar spine. The weight of the lower body (W_p) is supported by the knee support (N_knee) and the floor reaction force (N_floor), thus reducing the force transmitted to the lower body.

Table 4. List of parts and materials for the leg support and standing

Parameter Class	Variable	Value Used	Source / Justification
User Metrics	Target Population	Filipino Mfg. Workers	Study by Del-Prado Lu, 2007.
	User Mass (m)	90 kg	Estimated 95th percentile weight + 5kg PPE/Clothing allowance.
	User Height (H)	175 cm	95th percentile stature approximation based on popliteal/hip data.
	Hip Height (H_{hip})	96 cm	95th percentile Male Hip Height.
Biomechanics	Leaning Angle (θ)	15°	Standard ergonomic “perching” angle relative to vertical.
	Weight Distribution	60% Seat / 40% Feet	Typical load split for semi-standing postures [1].
	Center of Gravity (COG)	L4/L5 Vertebrae	Approximate anatomical center of mass for torso stability.
Mechanical	Gravitational Accel. (g)	9.81 m/s²	Standard physical constant.
	Friction Coeff. (μ)	0.6	Kinetic friction for Rubber (FP-001) on Industrial Concrete/Tile.
	Safety Factor (SF)	2	Recommended margin for dynamic loading (impact/dropping into seat).
	Max Vertical Load (F_y)	1,079 N	Calculated limit including safety buffer (Mass x g x SF).
Material	Locking Material	Stainless Steel	Can withstand calculated shear stress.

Table 5. Simulation assumptions and constants

Part Code	Part Name	Material	Description
SP-001	Support Platform	High-Density Polyethylene (HDPE) or Aluminum Alloy	This is the main surface where the user’s legs will rest. HDPE is lightweight, durable, and has good impact resistance. Aluminum alloy is strong, lightweight, and resistant to corrosion, making it ideal for long-term use.
AL-001L	Adjustable Hollow Shaft (Left Leg Assembly)	Aluminum Alloy or Stainless Steel	These are the legs, which are used to change the angle and height of the machine. Aluminum alloys are preferred because of their strength, but are very light in weight; stainless steel provides robustness as well as resistance to wear.
AL-001R	Adjustable Hollow Shaft (Right Leg Assembly)		
LM-001H	Locking Mechanism (Height Locking Mechanism)	Stainless Steel	This mechanism allows the legs to lock at any desired height and angle. Reinforced nylon is strong, resistant to wear, and very lightweight; stainless steel ensures durability with a secure lock.
LM-001A	Locking Mechanism (Angle Locking Mechanism)		
HJ-001L	Hinge Joints (Top Hinge Left)	Stainless Steel or Brass	These pivot points collapse the legs and offer flexibility. Stainless steel provides a great amount of strength and resistance to corrosion, and brass provides good durability while moving smoothly.
HJ-001R	Hinge Joints (Top Hinge Right)		
HJ-002L	Hinge Joints (Bottom Hinge Left)		
HJ-002R	Hinge Joints (Bottom Hinge Right)		
FP-001	Base Foot Mat (Left Foot Pad)	Rubber or Thermoplastic Elastomer (TPE)	The foot mats are attached to the bottom of the legs to provide grip and stability. Rubber or TPE is ideal as it provides good traction, cushioning, and non-slip properties.
HA-001L	Height Adjuster (Left)		

HA-001R	Height Adjuster (Right)	Aluminum Alloy or Stainless Steel with Plastic Components	This is the mechanism used to adjust the height of the device. Aluminum alloy or stainless steel provides strength, while plastic components (e.g., knobs or sliders) can offer ease of use and reduce weight.
AA-001L	Angle Adjuster (Left)	Aluminum Alloy with Polyurethane Coating	This mechanism allows for the adjustment of the device's angle. Aluminum alloy ensures strength, and a polyurethane coating can provide a smooth, non-slip surface for better control.
AA-001R	Angle Adjuster (Right)		
FS-001A	Fasteners (Screw Set A for Platform)	Stainless Steel	These are the screws and bolts used to assemble the device. Stainless steel is recommended due to its corrosion resistance and strength.
FS-002B	Fasteners (Bolts Set B for Legs)		
CF-001	Collapsible Frame (Main Frame)	Carbon Fiber Reinforced Polymer (CFRP) or Aluminum Alloy	The device includes a collapsible frame for added portability, CFRP provides an excellent strength-to-weight ratio, while aluminum alloy offers durability and ease of manufacturing.

The device allows the user to lean on the support, thus effectively reducing the weight of the user by 60%, which in turn reduces the force transmitted to the lower body. For a user weighing 90 kg, equivalent to 883 N, the reduction in axial force of 530 N acting on the knees and ankles is shown below:

$$Load\ Relief = 883\ N\ x\ 0.60 = 530\ N$$

Furthermore, the vertical adjustment capability allows the user to achieve a trunk-to-thigh angle of approximately 135°. This "neutral" posture significantly reduces lumbar disc pressure compared to the 90° angle of seated work or the 180° angle of static standing, effectively mitigating the risk of musculoskeletal disorders associated with prolonged standing.

3.4. Comparative Analysis with State-of-the-Art Interventions

The simulation results and biomechanical analysis clearly indicate that the proposed standing device provides better ergonomic results than the existing state-of-the-art methods reported in the literature. This is because of the three major design innovations: multi-point biomechanical offloading, local anthropometric calibration, and material-to-weight ratios.

3.4.1. Superiority over Traditional Sit-Stand and Leaning Stools

The conventional leaning stools are known to provide single-point support to the user, which is centered around the buttocks. Although this design helps in reducing the loading on the lower limbs, research has shown that this. Design often tends to push the user into a leaning position, which can result in an unintended increase in the shear force on the lumbar spine and erector spinae muscles [8].

The designed system helps in overcoming this problem by providing a multi-point support system that includes the lumbar region, buttocks, and shins.

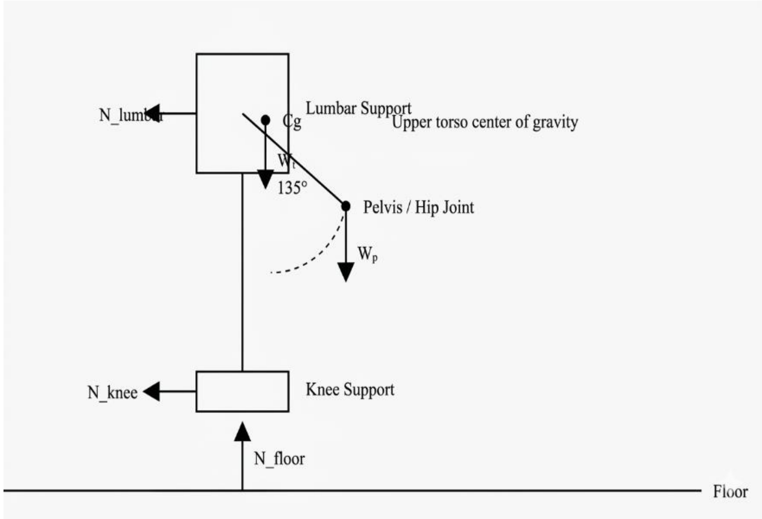

Fig. 4 2D Free body diagram

The system helps in actively supporting the lumbar region and shins, which helps in enforcing an open hip position of 135 degrees. As seen in the biomechanical simulation, this particular design is able to successfully unload 60% of the user's weight (530 N) while maintaining a neutral spinal position that is free from stress.

This is an important parameter that is not met by the conventional single-point leaning stools without affecting the stability of the user's posture.

3.4.2. Practical Advantages over Wearable Ergonomic Exoskeletons

The "wearable chair" exoskeleton has been extensively researched in recent literature. Although these exoskeletons are excellent for mobility, they have many limitations, such as heat stress, high pressure points, and the inability to walk naturally [16]. The designed standing assistance system offers the same weight-offloading advantages without the physiological limitations of wearable systems. By transferring the weight of the structure to an independent anti-skid floor platform (FP-001) instead of using strapping systems on the legs of the user, the system avoids pressure points during motion and is highly portable.

3.4.3. Structural Optimization vs. "One-Size-Fits-All" Commercial Models

Most commercial standing aids rely on generic, global anthropometric information and generic polymer locking mechanisms, which often result in suboptimal user accommodation and durability. The proposed design ensures optimal structural integrity and user accommodation through anthropometric calibration. By specifically using the target demographic's anthropometric information, such as increasing the seat width to 43 cm and the foot base to 31 cm, and requiring the use of structural-grade stainless steel in the high-torque locking joints (LM-001H), the design ensures a safety factor of more than 2.0 for a 95th percentile load (1,079 N). This localized engineering design ensures greater durability and a better percentage of accommodation than the generic commercial designs.

4. Conclusion

Prolonged standing in the working environment is a serious risk factor for the development of Work-Related Musculoskeletal Disorders (WMSDs) and fatigue. In response to this important ergonomic problem, the study has successfully designed and developed a portable and fully adjustable standing aid device specifically suited to the needs of the working population. By incorporating anthropometric data from 1,805 Filipino manufacturing workers, the device was developed using the basic principles of "design for an adjustable range" and "design for extremes." This ensures full structural accommodation for a wide range of users, from the 5th percentile female to the 95th percentile male.

Simulations on the biomechanical and structural aspects of the device have confirmed its effectiveness and safety for use. The new design of the multi-point support system, which covers the lumbar area, buttocks, and lower legs, allows the user to maintain a neutral position of 135 degrees, often called "Perching." This improved positioning reduces the axial load and pressure on the lower limbs and lumbar area by about 60% of the user's weight. Furthermore, the static load analysis shows that using structural-grade stainless steel in the locking system, along with the anti-skid base, provides a safety factor greater than 2.0 against mechanical failure and displacement. This research emphasizes the importance of using localized anthropometry in industrial design. Unlike standard commercial "one-size-fits-all" options, the proposed standing aid provides an effective ergonomic solution that is portable, focused on the user, and optimized for biomechanics. Implementing this practical, user-centered approach in various high-standing work environments can significantly reduce the incidence of WMSDs.

Conflicts of Interest

The authors declare that there is no conflict of interest related to the publication of this paper.

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