Measure It: Proper Wheelchair Fit Is Key to Ensuring Function While Protecting Skin Integrity

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This continuing educational activity will expire for physicians on December 31, 2015.

PURPOSE:
To provide information about the impact of a proper wheelchair fit on the posture and function of wheelchair users.

TARGET AUDIENCE:
This continuing education activity is intended for clinicians with an interest in skin and wound care.

OBJECTIVES:
After participating in this educational activity, the participant should be better able to:
1. Recognize the importance and mechanics of proper fitting of wheelchairs.
2. Explain the ramifications of improperly fitted wheelchairs.
ABSTRACT

The objectives of this article are to help the clinician to better recognize the basic biomechanics of posture, describe the appropriate means to configure a wheelchair to permit proper postural support, and to identify common problems arising from improper wheelchair fit.

KEYWORDS: wheelchair, posture, wheelchair seating

INTRODUCTION

The seated posture is a functional posture, especially for wheelchair users. People use wheelchairs for a variety of reasons but share the functional need for assistance in mobility. For some users, a wheelchair is a means of conveyance, meaning that a wheelchair is primarily used for getting from point A to point B. Often, after reaching one’s destination, these users will transfer out of the wheelchair and sit elsewhere. Other users remain seated in wheelchairs during a variety of functional activities. For these users, a wheelchair goes beyond a means of conveyance and is used as the base of support while eating, exercising, recreating, working, learning, and any other activity in which one participates. Often, these 2 user groups require different types of wheelchairs and seating systems, but in both cases, they need a wheelchair that fits well and supports them in a functional seated posture.

Consideration of posture includes both wheelchairs and seating systems, which consist of a seat cushion and back/trunk support. Wheelchairs are chairs, so it is important to provide the structural support for the trunk, pelvis, and extremities. Cushions and trunk supports represent the supporting surfaces and have a direct impact on the user interface. Both the wheelchair and cushion have significant impact on overall posture. Other postural influences include the wheelchair user, his/her environment, and the task being performed. This article focuses on the wheelchair and, specifically, proper wheelchair fit. The objective of this article is to describe the impact of proper wheelchair fit on the posture and function of wheelchair users.

A seat, especially one that will be used for lengthy durations, should support the body in an upright and functional posture. The importance of posture and wheelchair fit has long been described with foci on various cohorts of wheelchair users. More recently, clinicians and researchers have highlighted the need to ensure a proper match between the equipment and wheelchair user.

Samuelsson et al collected complaints about their wheelchair seating systems from 38 users who attended a seating clinic. More than 90% reported seating discomfort or pain as their primary complaint. Assessing outcomes, the authors found that seating interventions had a positive effect on 80% of the clients. The most common intervention was delivery of a more adjustable wheelchair that could be properly fit to the user. In addition, 15% of the clients simply had their current equipment adjusted properly. One interesting finding was that wheelchair users also reported functional benefits from interventions that reduced their seating discomfort, providing an important link between these constructs. Cherubini and Melchiorri assessed how well 15 different wheelchair attributes and configurations met the needs of 150 individual users. Each attribute was deemed suitable or not suitable by 3 physicians, independently. Sixty-eight percent of wheelchairs were deemed to have an unsuitable attribute. The most common areas of deficiency were cushions, trunk postural support, and pelvic postural support. Adjustable components such as armrests and footrests tended to be suitable more often than nonadjustable components. For example, 40% of wheelchairs had improper seat dimensions (width and/or depth). Overall, this study found that the user interface, as exemplified by the cushions and postural supports, was the most problematic. These are also the attributes that are most individualistic and thus require assessment or evaluation. Similar results were found in a study of nursing home residents who used wheelchairs. About 60% of resident wheelchair users had an identified need for better wheelchairs and/or seating. Pain and discomfort, a need for repositioning, and an inefficiency in wheelchair propulsion were the most prevalent problems. Nearly half of the residents (46%) had a seating need that was related to skin integrity.

These 3 studies deliver a consistent message about the high prevalence of mismatch between users and wheelchairs and the consequences of such mismatches. Pain and discomfort can be a simple metric to indicate a need to address and improve the wheelchair and seating environment. Each of the articles advocated for a proper evaluation to inform the wheelchair prescription and fitting process. This is a prudent suggestion that has potential benefits in function and the prevention of pressure ulcers (PrUs).

A recent efficacy study of wheelchair cushions in nursing home residents explicitly stated that cushions alone cannot protect skin; a properly fitted wheelchair is also needed. Furthermore, the authors’ state, “Poorly fitting wheelchairs are likely to result in poor posture that will result in higher pressure and increased PrU risk.” One of this study’s interesting findings was that persons who were independent in mobility had significantly fewer PrUs than did those dependent in mobility. This is an important result because it highlights the value of function by linking activity to PrU prevention.

Taken collectively, these studies provide a link between good posture, proper postural support, and the prevention of PrUs. They also concluded that good posture leads to better function,
which results in improved health outcomes. A simple review of posture can refresh clinicians’ knowledge of seating that can be applied to wheelchair users and nonwheelchair users alike. The principles of biomechanics as applied to posture are applicable across a wide span of persons, seats, chairs, and environments.

BIOMECHANICS OF POSTURE

The seated posture has been extensively studied for many years, with a great emphasis on ergonomic perspectives. One important ergonomic finding is that seating is not a static activity. In fact, moving while seated has both functional and health implications. Thus, it is important for everyone to move even while seated, and this also applies to wheelchair users. The biomechanics of posture can be complex when including dynamic activity. For the purpose of this discussion, postural biomechanics will be limited to forces and anthropometry during quiet sitting.

In sitting, the majority of body mass is transmitted through the pelvis to the buttocks and on to the seat surface. This results in the pelvis being the most important load-bearing site and, as a result, should garner substantial attention when evaluating posture. Body weight is also transmitted to the backrest through the trunk and the floor or footrests via the lower extremities and feet. These forces result from the gravitational influence on body mass, but the seating system has a significant impact on how these forces are distributed over the contact areas. Remembering that pressure = force/area, and localized pressure is the defining cause of PrUs, the relationship between distribution of force onto the supporting surfaces and tissue integrity becomes evident. Gravitational forces act downward and are responsible for the pressures on the body. Body weight dictates these forces, but how well they are distributed is a function of posture. Individuals increase the pressure on the buttocks by leaning slightly forward off their backrest or by raising their feet off the ground. This causes the buttocks to support the entire body weight, and decreased contact area leads to greater pressure. However, another important force is ever-present during a seated posture.

Frictional forces also exist at the seat surface, backrest, and foot support. Friction, by definition, is the force that resists sliding between 2 bodies. Friction is directly related to 2 things: the normal force between the bodies and the surface of contact. So, both normal and frictional forces are a function of the mass of the body segment and the postural alignment of the body with respect to the seat. Figure 1 illustrates the normal and frictional forces that are imparted onto the body by the chair and the ground.

To demonstrate, consider sitting in a regular chair. Anytime a person leans against the backrest, the backrest imparts an equal and opposite force that serves to push the person out of the chair. This reaction force is counteracted by frictional forces at the seat and feet. This is easy to experience. Sit on a chair—a hard seat, like a dining room chair is best for this demonstration. Lean against the backrest, and the body slides forward. This sliding tendency is counteracted by the friction on the seat. Lifting one’s feet off the ground causes more sliding. Next, try leaning forward slightly so the back is no longer contacting the backrest. The sliding tendency will decrease. Because this forward-sliding tendency is ever present when sitting with a backrest, achieving a stable and functional posture includes the need to manage this sliding tendency. Improper fit of a seating system can result in situations that do not provide requisite stability and can lead to poor posture that adds risk to skin integrity and lessens function.

With regard to wheelchair seating, the most common poor postures can be described as (1) a slouched kyphotic posture, and (2) asymmetry due to pelvic obliquity. By identifying these postures, clinicians can begin the process of identifying the causes and design proper interventions. A slouched kyphotic posture is characterized by posterior pelvic tilt and kyphotic spine (Figure 2). This results in loading at the sacrum/coccyx, hyperextension of the cervical spine to maintain forward gaze, and an increased forward-sliding tendency in response to the poor trunk and pelvic support. Posterior pelvic tilt results in the sacrum and coccyx bearing more load than in an erect posture. This is significant from a skin integrity standpoint. Considering the superficial location of this bony complex and its rough surface, an unnecessary increase in load bearing exposes
tissue to unnecessary stress. Unfortunately, a slouched kyphotic posture is fairly common because it results from many instances of poor fit. This will be evident in the discussion below.

Several anatomical markers can be used to identify a slouched posture. Palpating the anterior and posterior iliac spines (anterior superior iliac spine and posterior superior iliac spine, respectively) is a direct way to assess posterior pelvic tilt, but can be difficult because the posterior superior iliac spine is not easy to palpate when a person is sitting against a backrest. Palpating the coccyx with respect to the seat cushion is simpler and offers assessment of the sacral-coccyx orientation in the sagittal plane, as well as its load-bearing status. Moving up the body, a kyphotic thoracic spine can be identified by the relative locations of the acromion and mastoid processes. These should be aligned in an erect posture. As kyphosis increases, the head translates forward with a concomitant extension of the cervical spine (Figure 2).

Pelvic obliquity is an asymmetric posture in the frontal plane. It can be identified by palpating the iliac crests and is defined as one side being lower than the other. A pelvic obliquity can be a fixed deformity that is not readily corrected or a flexible asymmetry that can be corrected with proper postural support. A seating evaluation, often performed by a physical or occupational therapist, can distinguish a fixed versus correctable pelvic obliquity. A correctable pelvic obliquity can result from a variety of reasons linked to a poor wheelchair, such as sitting slightly to one side of a sling wheelchair seat or from having to lean over to reach an armrest, or to achieve requisite trunk stability.

In the next section, the relationship between the wheelchair and posture will be explored, highlighting the postural effects of inadequate support offered by the wheelchair.

MATCHING WHEELCHAIR DIMENSIONS TO THE USER

The biomechanics of wheelchair seating can be considered a subset of the larger realm of seating biomechanics. One difference is that the function of the wheelchair user is impaired in some manner that necessitates the use of the wheelchair. This reduced function extends beyond the lower extremities and can involve all parts of the upper body that are needed to achieve proper postural support. This fact, coupled with the fact that wheelchair users sit for extended periods, highlights the importance of a good seating system.

Several authors have written about wheelchair seating, the importance of evaluation, and consequences of poor posture and poor wheelchair fit. Readers are encouraged to access these for additional information and broader insight into the concepts presented in this article.

A wheelchair is a simple device with a substantial number of components. Figure 3 illustrates the key components of a standard wheelchair. Several of these components are involved in properly fitting a wheelchair to its user. To properly fit a wheelchair to a person, a minimum of 6 measurements must be considered (Figure 4), including measurements of the supporting surfaces of...
the buttocks, trunk, and upper and lower extremities. Not all these measurements are treated equally, and, as will be discussed, a few measurements tend to dominate the selection of a proper wheelchair. Indeed, wheelchairs should be ordered or adjusted to match all 6 measurements to the user.

**Seat Width**
Most wheelchairs are ordered or selected for a person according to seat width. This is because wheelchairs tend to be categorized by seat width because that is a nonadjustable measurement. Wheelchairs come in a wide range of seat widths; however, most adult models progress in 2-inch increments starting at 16 inches. Seated hip width is the anthropometric measurement that is used to correctly prescribe wheelchair width. The proper wheelchair has the most narrow seat width that allows the user to sit without direct pressure on his/her hips. Direct pressure can come from the armrests, clothing guards, or tires and can lead to discomfort or skin problems.

Most seat width problems occur from placing someone in a wheelchair that is too wide. This has several consequences, including the following:

- Using a wider wheelchair than is necessary reduces maneuverability and accessibility. Maneuvering a wider chair through doorways and other indoor spaces is more difficult, so there is no benefit from using an unnecessarily wide chair.
- Access to the hand rims is hindered if the chair is too wide. This reduces the ability to propel the wheelchair efficiently (Figure 5).

**Seat Depth**
Seat depth is the second dimension that defines many wheelchair models. A 16-inch seat depth is the most common, but longer seat depths are also available and should be considered for some users. The buttock-to-popliteal length is the anthropometric measurement that defines seat depth (Figure 6). Proper wheelchair seat depth is typically a little longer than the seat depths in desk or dining room chairs because greater support is needed under the thighs. A good guideline is to have about 1 inch between the popliteal fossa and the front edge of the seat.

If seated in a chair that is too long, contact at the popliteal fossa will result in discomfort, and the person will slide forward into a slouched kyphotic posture. Conversely, if the seat
depth is too short (Figure 7), proper support is not provided, resulting in the potential for the hip to rotate internally or externally due to poor thigh stability, and less stability of the buttocks on the seat due to reduced contact surface area.

**Seat Height**

Seat height has a direct impact on posture, propulsion, and transfers. In most wheelchairs, seat height is greater than that of everyday chairs because wheelchairs are designed to keep the feet off the ground. Standard wheelchair seat heights are 19 inches before the addition of a cushion. Therefore, the total seat height is typically greater. Proper seat height is dependent on the height of the wheelchair user and his/her means of propulsion. Users who propel only with their hands will use footplates for support. These users should be able to sit with properly adjusted footrests so that their thighs are fully supported on the seating surface.

In distinction, persons who propel with 1 or both legs require better access to the ground. This typically requires a lower seated height. If a foot propeller is placed in a seat that is too high, he/she will slide forward in the seat in order to extend the hip and reach the ground (Figure 8). Sliding forward on the seat results in a slouched kyphotic posture and an increased tendency to slide forward. This tendency is even greater for foot propellers, because foot propulsion also acts to pull a person forward in the seat. Therefore, foot propellers require added attention to ensure a stable seated posture.

A slight conflict arises from the fact that transfers are made easier when getting into and out of a slightly higher seat (Figure 9). The need to keep the seat low to reach the ground to propel is in conflict with a desire to facilitate transfers into and out of the wheelchair. This underscores the need for individual evaluation of proper wheelchair fit.

Fortunately, most wheelchairs can be adjusted to different seat heights by changing the axle positions of the drive wheels and casters. This is a relatively simple adjustment that is illustrated in Figure 10. In this particular example, the drive wheels can be placed in either of 2 positions, and the caster forks have 3 possible axle positions. Therefore, the caster axle position can be used to alter the seat angle, as well as the seat height.

In addition, sitting height can be lowered using a drop seat, which is commercially available from many sources. A few cushions are also designed to facilitate foot propulsion by allowing the user to sit lower in the seat compared with sitting on a traditional wheelchair cushion.

**Footrest Length**

Footrest length affects the support of both the feet and the thighs and the clearance of the footplates and the ground. The
footplate must be about 1 to 2 inches off the ground to permit adequate clearance. If too low, the footplate can catch when traversing door thresholds or grade transitions. Footrest contact occurs most often during grade transitions, such as starting to go up a ramp or when transitioning between the ramp and flat ground when descending (Figure 11). The danger lies in the

Figure 8.
SEAT HEIGHT: FOOT PROPULSION

Figure 9.
SEAT HEIGHT: SIT-TO-STAND

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A seat height that does not permit access to the ground will encourage users to slide forward in order to foot propel.

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A higher seat is easier to rise from compared with a lower seat.
The fact that a moving wheelchair can tip forward if the footrests suddenly hit an obstacle. In fact, about half of wheelchair tips are in the forward direction.23 Therefore, footplate clearance is a safety issue that must be considered when adjusting the footrest length, but proper adjustment is also reflective of the user's height. The proper footrest length is best determined by assessing the thigh and foot as the footrest height is adjusted. The thigh should contact the cushion surface, and the foot should be fully supported with enough weight to maintain stability on the footplate. A footrest that is too high results in the thigh being raised off the seat surface (Figure 12). This flexes the hip and reduces the contact area at the buttocks, resulting in elevated pressures on buttock tissue and lessened ability to overcome the forward-sliding tendency. Conversely, footrests that are too low result in poor foot support. The wheelchair user will seek foot stability by sliding forward in the seat. This results in a slouched kyphotic posture and all its consequences (Figure 13).

**Armrest Height**

Armrests serve a valuable postural support role for many users. They come in a variety of designs and lengths, all with their benefits and drawbacks. For instance, a desk length armrest pad is shorter to allow the user to wheel closer to a table or desk; however, because the pad is shorter, it offers less forearm support. Armrest height is adjustable in many chairs. Proper height is determined by adequate support under the forearms while in a comfortable and erect posture. If the armrests are too high, they force the user to elevate his/her shoulders, leading to discomfort (Figure 14) and, most likely, nonuse of the armrests. Conversely,

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**Figure 10.**
**CASTER AND DRIVE WHEEL AXLE POSITIONS**

Most wheelchairs offer multiple axle positions (arrows) to permit adjustment of seat height.

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**Figure 11.**
**FOOTREST LENGTH: TOO LOW**

If footrests are adjusted too low, contact with the ground can lead to tips and falls.

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**Figure 12.**
**FOOTREST LENGTH: TOO HIGH**

A footrest that is adjusted too high will provide inadequate thigh support and can lead to discomfort and instability.
if the armrests are too low, the user must lean forward or to the side to reach them (Figures 15A and 15B). Leaning to the side creates a pelvic obliquity and will elevate the pressures under the lower side, while forcing the user to laterally flex his/her trunk in order to maintain an erect head orientation. A simple adjustment is able to avoid this poor posture.

**Backrest Height**

The height of the backrest dictates the support afforded to the trunk. Chair backrest heights vary considerably according to the type of chair. For instance, dining room chairs have lower backrest heights than car seats. Typically, chairs with lower backrests permit more arm and trunk movement, whereas chairs with higher backrests offer greater support.

Wheelchairs tend to come with a standard backrest height of 16 inches; however, many wheelchairs offer a range of backrest heights. The functional backrest height, relative to the person, is dependent on the person’s trunk length and the thickness of the seat cushion. For most people, a 16-inch backrest height will support the thoracic spine below the inferior scapula angle. This is an acceptable level of support for many people that also allows freedom for the scapula to move freely. Sitting with a backrest that is too short can lead to postural instability. A person with little or no trunk control might need a backrest that rises up to the scapular spine. More likely, poor fit results when a backrest is too high for a user. Wheelchair users tend to do a lot of functional activity from a seated position; thus, they need to reach in various directions and access the push-rims of the wheelchair. This reach and access can be hindered by a backrest that is too tall. In addition, a backrest that is too tall can push the trunk forward too much by contacting the full scapula. This will result in postural instability, and the user will respond by sliding forward on the seat into a slouched posture.

**Sling Seat and Backrest Upholstery**

One of the most common problems with wheelchairs can be attributed to upholstery that needs to be replaced. Upholstery stretches over time, resulting in seats and backrests with too much curvature or “sling.” Overstretched sling upholstery offers a poor support surface and promotes a poor seated posture.

Excessive backrest sling allows the trunk to collapse into kyphosis because of inadequate support. The poor posterior pelvic support offered by unsupportive upholstery also allows the pelvis to adopt a posterior pelvic tilt. The result is a pronounced slouched kyphotic posture caused by worn upholstery (Figure 16).
Figure 15.
ARMREST HEIGHT: TOO LOW (A AND B)

Sling seat upholstery is a curved supporting member. Some cushions will accommodate for this by using a rigid base, but most do not, so the user sits on a curved surface. A slightly curved surface will not have a significant impact, but worn out and overstretched upholstery will contribute to poor posture. Unless the person sits in the exact middle of the seat, the pelvis will orient into an obliquity (Figure 17).

Upholstery is not designed to last forever. It is a soft good that can be easily replaced. One can purchase replacement backrest upholstery for less than $40 and seat upholstery for less than $60.

SUMMARY
This overview of posture and wheelchair fit did not make any reference to diagnoses of wheelchair users, but did make many mentions to function. This was a volitional decision based on the fact that wheelchair use is based on a functional impairment, and people with many diagnoses use wheelchairs. With respect to the content of this article, function includes many constructs, such as the ability to stand or ambulate, postural stability and control, including the ability to reach and lean, and the means by which one propels the wheelchair (upper extremity, lower extremity, or a combination of both). These and other functional abilities have a direct influence on the type of wheelchair and seating system

Figure 16.
SLING UPHOLSTERY: SLOUCHED

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that should be considered. At a basic level, persons spending little time in a wheelchair will have different needs than someone who sits in a wheelchair for 12 hours a day. A person who is independent in propulsion has different needs than a person who cannot move about on his/her own. A common need for all users, however, is to have a properly fitting wheelchair that supports the body in a seated posture.

Persons with a high level of postural control will typically need less postural support. This may be manifest by a chair with a lower backrest and no arm supports and configured to be less stable (ie, easier to “pop a wheelie”). Persons with good trunk control can be expected to perform weight-shifting activities that redistribute loading over the buttocks. Most functional movements involving the trunk have an impact on the pressure and blood flow at the buttocks. This underscores the need to promote function by putting people in properly fitted wheelchairs.

In distinction, persons with very limited function will rely on the wheelchair and seating system to provide stability. These are also the users who may be less able to reach and lean and perform weight shifts to protect their skin. People who sit statically are at particular risk of PrUs, so other interventions must be considered. Variable-position wheelchairs are available that alter body posture relative to gravity and result in changing the body mass borne by the buttocks. Although a full discussion is beyond the scope of this article, several sources of information can be accessed.

Because wheeled mobility and seating has both functional and medical implications, outcomes instruments can be very useful in assessing a patient’s or client’s current situation as well as evaluating interventions. A range of instruments have been developed and include tools that cover wheelchair use (ie, ATOM, WHoM, FEW, and seating/posture [i.e., Seating Intervention Tool, Seated Postural Control Measure]).

In closing, both evidence and simple logic suggest that many problems can arise from sitting persons in poorly fitted wheelchairs. Contractures, pain, and PrUs represent medical complications with reduced independence and activity representing the functional consequences.

Pain appears to be a useful metric to identify problems with the wheelchair and/or seating system. When combined with a quick postural assessment, poor fit or a poor match between user and wheelchair can be identified. Clinicians regularly assess position in bed and evaluate pain in hospital patients and residents as a means to prevent PrUs, so evaluating posture and pain while seated in a wheelchair is just as important.

**PRACTICE PEARLS**

- Research demonstrates that a properly fitted wheelchair enhances comfort and function while preventing PrUs.
- A wheelchair cushion cannot overcome a poorly fitted wheelchair to protect skin from breaking down.
- A slouched posture, characterized by posterior pelvic tilt and a kyphotic spine, results in excessive pressure on the sacrum and coccyx.
- Common causes of a slouched posture include seat depth that is too long, a seat that is too high, and footrests that are too low.
- Wheelchair upholstery wears out and should be replaced periodically. The wheelchair itself will last much longer than the upholstery.

**REFERENCES**

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