Abstract:
Use of evidence-based strategies to reduce the report of symptoms for seated work.

A qualitative measure for neutral spine posture and an indirect functional measure for the muscle strength to sustain that posture were tested in combination as field measures to locate the chair and work surface support, and to allow sufficient mobility to reduce the health risks for seated work. The method to determine chair height was tested for reliability with a sample of convenience among ergonomics consultants in 2006, and those data showed a highly significant correlation coefficient (> 0.9) between raters and subjects. The process to integrate the work surface and the chair were twice tested for outcomes in a Fortune 500 company with people who had conventional online ergonomic instruction and intervention, but still reported increasing pain. Inability to access Human Relations or Workers' Compensation data meant the initial baseline responses for each subject condition were considered a nominal control.

The first study was a retrospective single-survey design done in 2015. One thousand people were provided a consultation to integrate the office chair and work surface. They were then given a survey from one to five years after the completed recommendations that asked them to quantify any change to their symptoms and productivity as the result of that consultation. 187 respondents (18.7%) ranked their level of improvement since the intervention on a 5-point Likert scale (much better, somewhat better, no change, somewhat worse and much worse), and indicated subsequent changes in productivity on a 7-point scale (much better, somewhat better, slightly better, no change, slightly worse, somewhat worse and much worse). Most of the respondents (92%) reported their symptoms were either much better or somewhat better, and most respondents (94%) reported they were more productive. None were worse.

The second study was a repeated measures survey done in 2018 for 233 people whose symptom data were collected prior to their initial assessment. These clients identified their primary symptomatic body part and rated the frequency and severity of their discomfort on a five-point Likert scale (very low, low, moderate, high, very high). A follow-up survey with the same questions was provided from six to eighteen months after the single on-site ergonomics consultation and after the recommendations were completed. 134 people (57%) responded. Paired pre-test and post-test comparisons showed a significant 83% average reduction in the reported symptom severity and frequency for the low back group (n=80) and reported an equally significant 80% reduction in the severity and frequency of discomfort for the upper quarter symptom group (n=54). None were worse.

These data suggest that sensitive field measures for posture, stature and strength can be readily used to integrate a seated work station, and that process may offer significant reductions in the report of musculoskeletal symptoms.

Introduction:
The ergonomics consultant can choose from a wide range of chairs, work surface designs and products for computer input, but fifty years of American ergonomics practice have not made a significant reduction in the incidence, severity or the cost to treat low back disorders (Marras). “Sedentary posture” by definition includes any and all manner of seated positions, but current ergonomics practice does not make any clear distinction for the differences in those seated postures. The practice also does not address the nature of the work that may require repeated changes in seated posture. For instance, seated work tasks that are done with the torso forward and upright need more sustained postural muscle activity, as opposed to work that can be done in relaxed and reclined postures. A general strategy to simply avoid seated work may be over-simplified unless it clearly defines specific postures that may be problematic in the workplace. This paper will examine the evidence for physiologic risks associated with different work postures, and attempt to clarify the musculoskeletal demands observed. An alternative strategy to integrate the chair and work surface is presented along with outcomes for that method to demonstrate that more sensitive measures can effectively reduce the report of musculoskeletal symptoms common to seated work.

Posture and strength are criteria that can be simply measured, and have not been sufficiently explored to refine a more purposeful chair adjustment strategy for the end-user. The author’s clinical experience treating cumulative trauma with Physical Therapy and his consulting experience to review the injured client during work suggest that the rate and severity of musculoskeletal symptoms are expected to improve when the subject can both understand and accept more effective chair and work surface support to help sustain neutral spine postures. This paper presents a field test of spine posture that is used concurrently with a functional test of postural muscle strength. The techniques were combined and tested for field validity and showed significant reductions for the report of symptoms. The use of those measures to integrate the seated workstation is provided in further detail below.

Background:
Published research is clear that apart from musculoskeletal problems, increased physiologic disease risks like heart disease, diabetes and cancer are associated with leisure sitting (Patel, Warren, Owen, Hamilton), but those data should be further clarified in the context of cause and the relative magnitude of risk. Patel published a study of 124,000 men and women who were disease-free at the start of the study and followed them for 14 years. That study compared the mortality for the least and most active groups in that population, and found a significantly higher mortality for those who were the least active and spent the most time in leisure sitting. The study made a clear distinction to measure only the time spent in leisure sitting without any reference to the amount of time sitting at work. Those data showed an increased risk of mortality for the least active and those who sat most at 1.71 and 1.81 times greater, for men and women, respectively. The median age of that population was 64 years old, which may not be a fair representation of typical working populations. Unfortunately, that study has been

frequently cited to encourage employers to use sit-stand workstations to minimize health risks in work environments.

Van Uffelen published a meta-study of research the same year that specifically studied the association for the amount of time sitting at work and increased risks for diabetes, obesity, heart disease, cancer or death from all causes. 43 papers that addressed that question were reviewed, and twenty found no causal relation for the amount of sitting time at work and a greater risk for those diseases. The remaining 23 papers were equivocal regarding the time seated at work and the consequent risk for disease; some studies found an adverse effect for some diseases, like diabetes, and other papers found a beneficial effect for the same disease.

It is difficult to draw conclusive evidence for the rationale to stand when comparing even the most authoritative epidemiological studies and comparative reviews of the literature. A British study (Stamatakis) followed the mortality of 11,168 people for more than 12 years and concluded that sitting occupations are linked to increased risk for all-cause and cancer mortality in women only, but they found no association for cardiovascular mortality in men or women. A Canadian study (Smith) of 7,320 people had a different finding: a 12-year follow-up concluded that men with predominantly standing work had a two-fold greater risk of heart disease, compared with occupations that predominantly required sitting. They further concluded that for work that required combinations of sitting, standing and walking the results differed for men and women, with lower cardiovascular risks for men and higher risk estimates for women.
Another Canadian study (16,586 people studied for twelve years) drew yet another conflicting conclusion: they specifically looked at the amount of standing time and mortality (Katzmarzyk) and determined that standing may not be hazardous, particularly since they found mortality rates that declined with higher levels of standing. The evidence drawn from a meta-study for higher levels of standing with 50 peer-reviewed articles (Coenen) concluded that substantial standing (>4 hours, daily) was associated with low back symptoms. Another review of the literature (Waters) simply stated there was ample evidence that prolonged standing at work leads to adverse health outcomes.

If sit-stand workstations can generally lower musculoskeletal risks (different from the relatively low physiologic disease risk from sitting at work) the research is not entirely clear. A smaller scale (33 computers users) and short-term (4-6 weeks) study reported reductions in the severity of upper body symptoms using a height-adjustable table (Hedge) but not significant changes in low back symptoms. Self-identified computer users with chronic low back pain (46 university employees) were studied using standing workstations for twelve weeks (Ognibene) and reported a significant reduction in low back pain, but that study did not examine the neck-shoulder-arm problems associated with office work, particularly that product used a keyboard tray. A meta-study of fourteen articles that reviewed standing workstations (Karakolis) found only three papers that showed significant improvement in reported discomfort outcomes with sit-stand workstations, and they concluded that there may be only perceived symptomatic benefit from the sit-stand workstation, with no evident loss of productivity.

Reviews for the long-term experience with standing workstations suggests people do not want to stand at work: one study showed that after having a sit-stand workstation for a year, approximately 60% of the group stood less than once a month, and less than one in ten adjusted their table daily (Straker). Another paper suggested that people need to be directed to stand to work when provided an adjustable table (Robertson). Other research reported that as many as twenty percent of people may want to stand at work (Gilson). Unfortunately, those who choose to stand are not likely change the health outcome for those who remain sitting. Regardless of whether using conventional desks or sit-stand workstations, directions only to take short-term breaks away from the desk have shown a significant reduction in the report of spinal discomfort at the upper back, mid-back and low back, and a favorable, but non-significant 10% improvement in productivity (Davis).

The primary concern of any intervention is "do no harm," but there are medical concerns to adopt global prescriptions for standing workstations. One study specifically looked at incrementally measured increases in work effort as a risk factor for the progression of ischemic heart disease (Krause), which affects about eleven percent of the U.S. population (CDC). That study was part of the Finnish Heart Study and accounted for most of the confounding variables of heart disease—they found that when men moved from seated work to: standing a little, moderately, a lot, or all the time, the relative risk for the progression of ischemic heart disease was calculated to increase from three to nine times, respectively. Those data suggest that the added risk to use a standing workstation for those with ischemic heart disease is far greater than the risk of sustained leisure sitting, yet there is typically no regular caution or screening to recommend when to use a standing workstation.

Putting aside estimates for the risk of physiologic disease work, musculoskeletal discomfort at work is prevalent, despite a considerably much lower rate for the report of injuries. A study of 333 office workers (Johnston, 2008) showed that 53% reported mild neck pain related to their work tasks, and 14% reported moderate neck pain. Fifteen European countries report work related pain, and Bongers (2006) reported that 25% have neck and shoulder pain, and 15% have arm pain. Gerr (2005) studied 376 office workers, from whom 20% reported arm or hand symptoms and 31% reported neck or shoulder symptoms. The same author (2002) also studied 632 people of whom more than 50% reported symptoms in their first year on the job. Each of these studies attempted to show how general postural characteristics at the office workstation related to discomfort, and none of those studies were specific for observed spinal postures.

Determining seated spine posture:

The details of seated spine posture and the activity of the postural muscle to support the spine seem to be the critical elements to predict health risk and outcomes. Two of the most influential studies to identify postures and musculoskeletal risk factors are the lumbar disc pressure studies done with live subjects in different postures (Nachemson, Wilke). A summary of those data is presented schematically in Figure 1. The studies were clear that some positions exerted less pressure in the discs at the lumbar spine (pressures at the back are least when the torso is upright, relaxed and reclined) and worst when the torso is forward bent or slumped. It follows that reclined sitting and standing postures are preferred for work. Those study data have heavily influenced chair design, with many "ergonomic chairs" that only adjust to accommodate reclined postures. Reclined seated postures have since been encouraged for seated work, with the presumption that the work and workstation can then be adapted with other products (monitor arm, keyboard tray, footrest and slant board) to allow all seated work to be conducted in essentially the same reclined posture (Alan Hedge, personal communication).

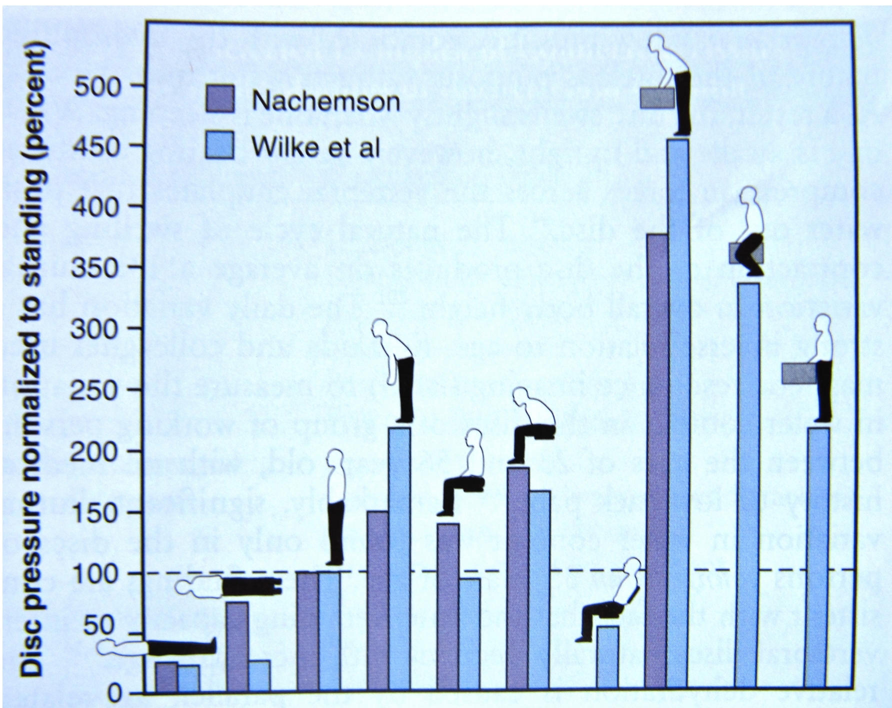

Figure 1. Posture and Lumbar disc pressure measurements. Standing posture (third from left) was normalized for both studies, and lumbar disc pressure was compared for different postures. Reclined seated posture (seventh from left) showed disc pressure measures that were approximately half that of standing. Lumbar disc pressures for Upright Seated posture for the Wilke study were similar to Standing, but Slumped Seated postures were consistently measured at a much higher pressure (sixth from left). After Nachemson and Wilke.

The American National Standards Institute (ANSI) has diagrammed the four basic postures that are expected at work (Figure 2.) These postures are presented as a continuum of effort from reclined seating which requires the least effort, to upright seating, declined seating and finally standing, which requires the greatest effort. Note that all of the torso postures demonstrate the best spine posture—meaning, that none of the examples include slumping. The author proposes that "seated postures" can be reasonably simplified into two categories: either reclined posture and upright, or forward posture. Reclined seating is clearly relaxed and passive, and shown with an apparent “neutral spine posture.” Upright and Declined Seating can be considered the same posture because of the need to engage postural muscle to maintain the torso upright—the only difference in the two upright seated postures is simply the change in height of the seat pan relative to the body stature.

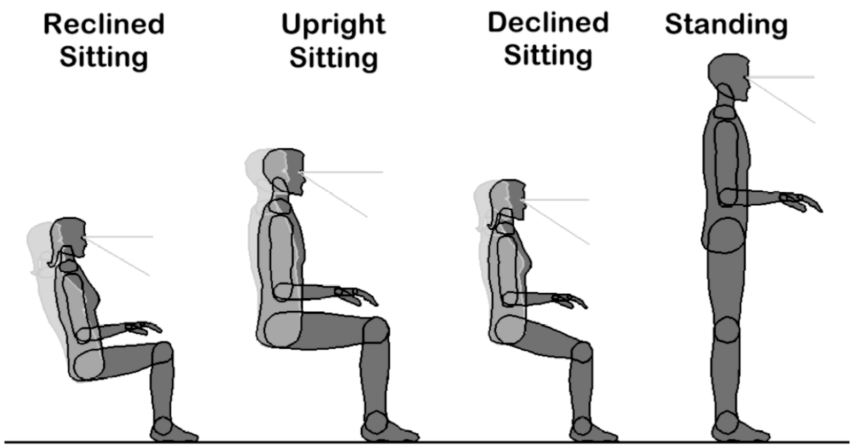

Figure 2. Schematic for typical work postures (After ANSI). The classic reclined seated posture is on the far left and requires the least amount of effort. Upright and Declined Sitting require increasing amounts of effort, and Standing requires the most. Note the similar torso orientation for Upright and Declined Sitting—the essential postural difference for the two middle images is the height of the seat pan relative to the body stature.

Unfortunately, without a clear strategy to first identify and then support neutral spine postures in the field, maintaining the best torso posture during work is surprisingly problematic. Slumping is the most relaxed posture, and usually does not cause any symptoms in the short term. The position of the pelvis may be too subtle for the untrained eye to distinguish during work and may not be considered a problem.

There are few tools that reliably identify seated spine posture in the field. The most rigorous measures of spine posture are quantitative research tools that typically show the precise angle and orientation between the bones, using either X-rays, MRI; or those relations are inferred from low back surface contours, inclinometers or the optical movement of markers on the bony landmarks—all done in a laboratory setting. The mid-position angle for the available range of motion at the spine is then considered acceptable for “neutral spine posture.” Quantitative laboratory measures of motion and position are preferred because they provide very specific objective measures and comparisons. The problem is that the complexity of these methods makes them completely unsuitable for field work, and laboratory studies can only approximate real-work conditions. Using reliable anatomic landmarks to identify spine posture during seated work is extremely difficult because the chair back support gets in the way of any surface contour measures at the back, chair armrests get in the way of the lateral view, and clothing obscures any useful bony landmarks.

The typical field measure for spine posture in sitting has been to use the **thigh-torso angle:** seated postures are "preferred" when the angle between a line at the thigh (from the hip to the knee) and the torso (a line from the hip to the shoulder) is greater than ninety degrees. In schematic terms, a thigh-torso angle greater than 90 degrees is considered "safe" and even greater angles are preferred. This method of spinal measurement seems consistent with the schematic postures shown in Figure 1, and reclined, relaxed seating demonstrates one "best case," (Figure 3.). Unfortunately, the thigh-torso angle does not account for forward and backward rotational movement at the pelvis, which is an important indicator of the low back posture, and may have a very small range of motion.

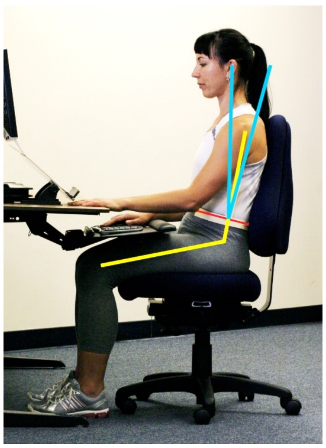

Figure 3. Photograph to show classic, reclined chair posture. The yellow line shows the thigh-torso angle used to identify optimal posture. The spine posture is then considered "preferred" when the angle of the thigh and torso is "open," or greater than 90 degrees. The brim of the pelvis is marked as a red line, and the relative angle from the tangent of that line to the head (the blue line-angle) also suggests the pelvis is generally oriented toward the head and the spine is close to "neutral posture," or near the mid-position of spinal movement.

In practice, there may be a very small observable difference between the best and worst postures. The lumbar spine movement is closely related to the position of the pelvis (Dunk). The expected range of motion for forward and backward rotation of the pelvis (in the sagittal plane) is 25 degrees, +/- 15 degrees (Panjabi), and that range was presumably estimated with both the hip and low back in their mid-range, or neutral postures. When the hip is close to 90 degrees flexion in sitting, tightness at the back of the hip may further restrict the range of motion at the pelvis. The injured client who presents with low back or hip pathology will be expected to have even less available range of motion. Much of the research literature recommends their subjects assume a "comfortable" seated posture, which may not position the spine in neutral posture (Beach, Kingma, Le, McGill, Nathan-Roberts, Schult). Not only is it difficult to see the mid-range of motion at the low back, the slumped spine at the end range of flexion is completely comfortable for most people and may not cause immediate symptoms. When work demands draw the upper torso forward, and the body is relaxed into a reclined chair there is a choice for one of two postures: the first, and the easiest is to maximize the support from the chair and sustain the slumped posture (Figure 4). The consequences of slumped posture will be detailed later.

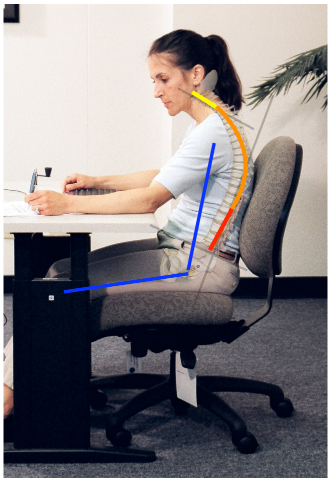

Figure 4. Photograph with spine overlay to show a relatively "open" thigh-torso angle (<90 degrees) and fully slumped spine posture. The example is shown using a chair adjusted for a passive, comfortably reclined posture, but the subject is doing work that requires forward shoulder reach and downward gaze—tasks which draw the upper torso forward; the result is a relaxed body with the spine very near the end-range of forward bending.

The second option is to maintain the upright torso by sitting forward at the front of the chair and use support from the legs and postural muscle to tip the upright torso forward, exerting greater effort to move into Declined Sitting (Figure 5).

Figure 5. Declined Sitting or "perched" posture. Typical upright torso posture seen to

do forward work using a chair that is adjusted for reclined posture. The body has now fully engaged the postural muscles, including the legs, to sustain the torso upright, and the chair can be adjusted to a height that allows forearm support on the work surface. Unfortunately, there is little support from the chair to prevent slumping.

The "perch," or Declined Sitting posture has several advantages in a height-adjustable chair. First, there is greater freedom and mobility to do forward work with an upright torso. Second, the height of the chair can be adjusted to meet the elbow height and take advantage of the work surface for forearm support. This posture limits support from the chair at the back and thigh, and the chair height is indirectly determined by the work surface height, ie, the chair is adjusted to meet the pre-determined work surface height. Ultimately, the legs are not in their best position to support the torso, and an easy transition from forward to reclined postures is compromised.

The problems with slumping well studied. When the body relaxes into slumped posture, the deeper muscles at the spine (multifidus mm.) completely relax within five seconds (Burnett 2009, Callahan, O'Sullivan 2006). When the slumped posture is repeated or sustained longer than a few minutes, the relationship of the ligaments, cartilage, muscle and even the joints in the back gradually stretch, or "creep" to allow more forward bending (Twomey, Little). As this stretch continues the muscles weaken (Kendall) and the proper movement in the joints become more compromised (Burnett 2008). The first sign of this degenerative process is the stiffness we may feel rising to upright standing from a sustained slumped seated posture (Beach). Continued stretch into forward bending ultimately leads to weakness of the deep muscles, resulting in pain at the segment that is compromised (Freeman, Hides). Fortunately, strengthening the same deep muscle group with increased activity or therapeutic exercise will often resolve the problem (Sung).

Apart from the musculoskeletal problems, physiologic disease risk is also linked to the slumped postural muscles and the resulting inactivity of an enzyme (lipoprotein lipase) that controls the normal hormonal levels of blood sugar, fatty acid metabolism and stress hormones (Bey, Hamilton, Healy, Owen). The mechanism of improved enzyme activity with active postural muscles explains why leisure sitting, which presumably is a sustained position of comfort, ie, slumped sitting, presents a far greater physiologic risk than sitting at work. It seems reasonable to expect that people at work need engage and change postures more than sitting at home. The physical movement at work may provide sufficient postural stimulation to restore the enzyme activity to levels that mitigate the physiologic risks from sustained slumped sitting.

One problem with sustaining good spine posture is that there is such a small range of motion between the best and the worst postures, and we cannot identify that worst posture as a problem. A simple and easy test of neutral spine posture becomes the primary tool the subject can use to adjust the chair; furthermore, the postural test can determine when changes in the work pattern may require a subsequent change in chair adjustment.

Some of the difficulty to maintain neutral spine posture is that seated work office work may require two different torso positions (Maigne, Leuder, Nathan-Roberts), either inclined forward or reclined, depending on the visual and manual demands of the work (Figure 6). Reclined bias tasks are those which do not require intensive gaze to the monitor or the desk surface, and which do not require repetitive shoulder reach to draw the upper torso forward. Such tasks are to conduct interviews, telephone conversation, casual reading in-hand and transcription/dictation or coding by a skilled typist. Often, more forward tasks are required at the same desk and are best served with the upright torso forward: handwriting, intense interest in the monitor, collaboration with written documents, use of a calculator. Increasingly, visual cues to the keyboard are seen, either with relatively unskilled typists, or with skilled typists who are frequently interrupted either by keyboard commands or intensive use of the mouse, then return to the home row requires a quick glance down to the keyboard. If the keyboard is below the work surface, additional neck bend is required which can further degrade spinal postures.

Figure 6. Schematic images to show the upright torso in forward and reclined tasks. The left image shows neutral spine posture in a relatively forward posture, used for multiple, mixed tasks on the work surface. The image on the right shows neutral spine posture in a reclined posture where the torso can relax into the chair.

Seated work that is vision- and detail-task intensive, like looking continuously at the keyboard or at visual target below the horizon (i.e., at a sewing machine or small parts assembly), writing, calculations or drawing on the work surface, or repeated forward shoulder reach is work that can be done more easily with a forward torso inclination (Figure 6. Left image, above). Work that requires client interview and conversation, extended telephone calls, general gaze to the horizon, or sustained keyboard entry that does not repeated vision to the keyboard (like skilled transcription or dictation) are tasks are more easily done from a reclined seated posture (Figure 6. Right image, above).

The postural problem is further compounded when there is a regular alternation in the forward/reclined work bias throughout any given work period. For example, there may be a pressing deadline to prepare for a call or a meeting, and that intensity is expressed as a forward task, possibly requiring additional mixed tasks (notes, reference) on the work surface combined with a high visual demand toward the monitor; when the call or meeting starts the task may then revert to a reclined posture, just to watch the monitor or talk on the phone. Because of the very small range of motion at the low back, proper support requires a change in the chair adjustment when the bias of the task changes.

Neutral Spine Indication:
Studies report the advantages of neutral spine postures for strength and freedom of spinal movement (Adams, Dolan) particularly in sitting (Pynt). Rather than include every joint in the spine, and every direction of spinal movement, we can simplify the observation to focus on a position of forward and backward bending at the low back (when viewed from the side, or sagittal plane), which is also the position that also allows the most rotation and side-bending (Panjabi, Adams, Dolan). By definition, that neutral posture is a position of the joint segments at or near their mid-range of motion where movement is possible, excluding the end-range of movement in either forward bending (flexion) or backward bending (extension).

In practice, when the postural muscles are engaged to correct the low back posture, the rest of the spine can more easily move toward neutral postures (Burnett). A technique is commonly used in clinical practice as a part of therapeutic treatment and exercise, and it is also a typical parental correction at the dinner table. The verbal cue is to “sit up taller, please.” The physical cue is a light palpation at the sacrum or the lower lumbar spine to either feel or to encourage some forward rotation of the pelvis. In practice, this movement cue is easily accepted, readily observed by both the client and the consultant, and can be consciously applied at work or home. This postural correction can also be done in either forward or reclined seated postures during work.

After neutral spine posture is clearly identified, the problem remains how to easily sustain that posture. The second goal is to locate a position where the muscles that support the spine can work most easily and most often, and then provide appropriate support. Seat height has been shown to make an important difference in the report of symptoms in seated work. Use of adjustable seat heights have demonstrated significant reductions in the report of symptoms at the low back (Wang) and again for neck and shoulder symptoms (Rempel 2007) among people doing predominantly forward tasks. Although neither of those studies explored the chair’s effect on spine posture in the field, presumably the adjustable chair height allowed the user to find a position that made it easier to sit up straight, and more easily facilitate the postural muscles.

Seat height method:
The author used a test of functional leg strength to select an optimal chair height for a seated subject. Presuming that leg strength to move the chair with an upright torso will change with the height of the chair, the critical dimension for chair adjustment is the height of the seat pan. Clearly if the chair is too tall or too short, the legs cannot exert their maximum effort to easily move and support the torso. This chair height would then be used as a standardized criteria to assess the individual’s dimensions for chair and workstation adjustments. If optimal leg and torso strength are determined with a

vertical torso posture in sitting as the "top dead center" of movement forward and backward in the sagittal plane, then the same fitted work surface height can then be used for arm support with either ten to fifteen degrees of forward tilt as well as ten to fifteen degrees of reclined chair tilt. Ultimately, the goal is to find the best support and mobility to sustain neutral spine posture for the expected transitions between forward and reclined tasks.

Forearm Support:

OSHA recommends use of an adjustable keyboard tray for computer work more than four hours daily, and the typical location for the keyboard height relative to the body has been previously suggested at two inches below the height of the elbow (Dainoff). This relative position of the keyboard works well for sustained and dedicated keyboard entry with minimal mouse use; it may not be the most effective strategy when the nature of the work changes. Completely dedicated data entry tasks were the predominant computer problem when computers were introduced to the workforce, but as software and data management has changed in recent decades, varied, mixed tasks on the work surface are more commonly combined with with heavy mouse use and intermittent, short entries at the keyboard.

Several papers describe significant symptom reduction in the injured population with the use of forearm support during computer work (Conlon, Cook, Gerr 2005, Hedge, Rempel 2006). Because there seems no clearly accepted guideline to locate the height of the work surface to replace the adjustable keyboard tray for mixed tasks, the new measures of strength and stature in sitting were uses as the criteria to include a specific work surface height in the ergonomic recommendations. Once the strong seated height is determined, locating the work surface height required close observation of the client spine posture at work. The height recommendation should allow full forearm movement across the surface without raising the shoulder ***and*** fully relaxed forearm support without slumping at the torso. Generally, this surface height is about one inch above the measured height of the elbow, when the subject is seated upright with hands in the lap. Client girth and preference may require testing at several heights with observation of movement at the shoulder for confirmation. When this surface height is determined, it will allow the torso to have forearm support with the torso leaning forward 10-15 degrees and also reclined 10-25 degrees.

Seat Pan tilt:

When posture is corrected to an upright, neutral spine, the base of the spine rotates forward on the pelvis, and the relationship of the legs to the pelvis is altered slightly. This movement is influenced primarily by the height of the pelvis on the seat pan, but also by the angle of the seat pan. The practical experience of this chair adjustment is easily appreciated by most people, certainly in reclined postures, but particularly when the postural correction is done with forward tilt of the chair with an integrated work surface for resting forearm support.

An article was published that stated the seat pan angle had little influence on the kinetic chain of the spine (Hamaoui), but there were several important differences in that research and the work which is presented here, First, their selection of seat heights was determined by an algorithm that was proposed to predict chair dimensions to fit adolescents in general, so the height was not necessarily specific to the subject tested. Second, the subjects in the that study were asked "to sit comfortably," which unless there is some other criteria to either indicate or control for spinal posture, the subject may be likely to slump and have less freedom to move through the spine.

The proposed process to find the best chair height does not measure the strength of any single muscle. More than 25 muscles in each leg work together (and antagonistically) with the long levers of the legs to simultaneously move the chair and stabilize the torso upright. An adequate test does not also examine the individual muscles between bones in the spine, but rather how the entire system works together using the chair height as a single variable. This seat height test is an attempt to show where all of these muscles can most easily work together to sustain upright postures and where the legs can properly stabilize the pelvis. Testing different heights of the chair will show when these muscles work easiest for the subject tested, thus demonstrate a chair height which is in the strongest functional position for that body.

This approach is a distinct departure from a consulting model where the expert determines every (predetermined) adjustment for proper body posture. In this practice the client determines the chair height, and the consultant simply guides the process. Previously unpublished work is presented below to show that a standardized test of the postural muscles to move the chair at several heights can very reliably determine a precise chair height with the torso upright. In other words, the testing process does not produce an arbitrary outcome, but one that is very specific for the individual.

When the best chair height has been established, and the back support is adjusted to support the torso in a conscious choice of neutral spine posture, the subject's height at the elbow and the eye are then measured. These measures of stature in upright sitting are then used to locate the height of the work surface and the visual targets, respectively. Rather than move the chair to meet an arbitrary work surface height, the work surface is then moved to meet the best strength and stature for the subject. Making the transition of chair support from forward to reclined postures is much easier after the best chair height has been determined and the chair will accommodate both forward postures with arm support and reclined postures supported by the chair.

Figure 7. Image of chair pan tilt and full forearm support. The work surface was used to allow support and mobility for the shoulder in both forward and reclined tasks. Full forearm support on the work surface is possible for both forward and reclined postures when the proper chair height has been established. Note that once the chair height has been determined, the principal difference in chair adjustment is the tilt of the seat.

After the workstation has been integrated with the user's dimensions, it becomes the user's responsibility to determine when the task at hand can be better supported with either forward or reclined chair adjustments. The simplest strategy for support may depend on the chair design. Ideally, the user can lock the chair in forward postures when specific forward tasks are required. The chair can then be unlocked for return to more reclined tasks.

Chair recline resistance can be usually be adjusted for the user to move the chair like a rocker, and balanced movements forward and backward can be accomplished with simply moving the head and shoulders. When the recline resistance is adjusted for the user's body weight, the transition between forward and reclined postures should be a simple adjustment of the chair mechanism. Unfortunately, the amount of resistance to allow balanced movement will not be sufficient to fully support the neutral spine in forward tasks. Simply stated, the body will ultimately press against the chair's recline resistance for support, and the chair will recline rather than provide support to keep the spine upright. Where possible, the most successful outcomes have been when the client can lock the chair in forward tilt for the duration of forward tasks, and then release the mechanism for reclined tasks.

Part I. Reliability of the Seat Height Test

Allowing the subject to choose the height of the chair raises an important question—is that process reliable, or is it just a haphazard approach? To answer that question, a research statistician was hired to design a study to reasonably determine how consistently the method worked in practice; the statistician was then given the raw data to determine a correlation coefficient for the process.

Hypothesis:
Anthropometric measures taken from upright and supported seated postures determined by functional leg strength should be consistent for that subject.

Method:
A sample of convenience was taken from a regular meeting of ergonomics consultants at an ergonomic chair showroom. These consultants had a wide range of experience, from novice to expert. The entire group was shown the basic criteria for a chair fitting and for caster-floor surface compatibility. Six volunteers from the group were self-selected as "raters," and six chose to be "subjects." Each of the subjects was confirmed to use an appropriate chair for the size and features, and the subjects' remained with the same chair throughout the experiment.

The group was then shown a process to test leg strength in the chair:

a. Position the seat pan level and move the back support away from the torso
b. With the subject in the chair, move the chair front-back and then side to side 12-15 inches at one height with the feet firmly planted
c. Change the chair height slightly (~ ½ inch, either up or down) and retest the effort for chair movement
d. Repeat the test until the easiest height was determined
e. Repeat the movement to extend the torso taller, and then move the lumbar pad forward to support the torso
f. Measure and record the heights at the elbow with the hands together in the lap, the eye, the popliteal fossa and the chair height, using a prior mark on the pan
g. The "rater" then moved the chair height to either top or bottom, and repeated the test with the next subject in sequence

Figure 8. Testing schematic. The subject was positioned with a level seat pan and one- to two-inches horizontal space behind the knee (red circle). The subject's torso was

positioned upright and the back support moved away from the torso. Keeping the feet firmly on the floor, the subject was asked to move the chair side-side and front-back at several heights until the easiest movement was observed. At that point, the back support was moved forward to support the upright torso and measures were taken.

The heights were measured as five data points to the closest one-quarter inch for each subject: chair pan height (a marked line on the chair to estimate the level of the ischial tuberosities), the knee height (popliteal fossa), both elbow heights (olecranon) and the height of a horizontal line between the eyes. After the measures were recorded, the chair was moved to the top height, and the test was repeated with another Rater. The first Rater then moved to the next Subject in turn to repeat the sequence. Raw data was then provided to the statistician who originally designed the study.

Data management:
Inter-rater reliability was calculated for the recorded data using Shrout-Fleiss random set mean k scores.

Results:
Inter-rater reliability for popliteal height, pan height, elbow height and eye height measures were greater than 0.94 for all measures: popliteal height: 0.967, chair pan height: 0.947, elbow height left: 0.966, elbow height right: 0.958, eye height: 0.986. The height of the chair pan correlated with the height of the popliteal fossa (0.848), but not as closely as the other measures, independently. 1.0 is considered perfect reliability.

Conclusion:
Interpretation of the data suggested that the method to test chair height and adjust the chair was readily repeatable in a group with a wide range of both accomplished and novice consultant skills, and those outcome data were remarkably consistent. Furthermore, the consistency of measures was in a chair that fully supported the neutral spine posture, at least in the short term. Because the process used a functional movement of the body to specifically measures leg strength with the upright torso, we can presume the postural muscles were positioned in a way to readily facilitate their strength and engagement.

The least consistent measure is the relationship of the chair height to the anatomic landmark at the knee—meaning that the angle of the thigh varied between subjects. These data suggest that leg strength may be a more valid determinant for chair height than using the relation of static anatomic landmarks (popliteal height to the chair, thigh-torso angles) or requiring the subject to adapt to fixed work surface heights.

Discussion:
Encouraging more functional movements for the hip and the legs to maintain the torso upright is a process that can be used to adjust the chair pan to a height that allows peak forces for those postural muscles. In other words, to choose a chair height where the translational movement of the chair is easiest when the torso is upright allows better

stability of the torso in the chair. Outcome measures based on strength should be consistent for each subject, because the strength and the stature for each subject are essentially unchanged during the testing process.

The angles measured for posture at the thigh and torso will likely differ between subjects because there are wide differences in strength and stature between subjects (muscle mass at the hip and thigh, and length of the thigh relative to the lower leg) that influence the height of the chair at which the functional posture is easiest. In other words, the chair height where each subject demonstrates their own best strength will necessarily differ between subjects.

Making small changes in chair height (less than one-half inch) will usually reveal an evident difference in the amount of effort to move the chair, and there will be observable differences in the acceleration and deceleration of the chair. Those outcome data can also be confirmed using an accelerometer program on a smartphone (HipTorque™), although that correlation has not yet been definitively explored.

The thigh-torso angle was not measured in this study. These data suggest that a more sensitive measure for spinal posture in sitting may have a greater value than thigh-torso angle. Furthermore, the ability to easily adopt or sustain best postures during an active and varied work routine may require more adaptive or dynamic measures. The author does not consider the alternative postural recommendations for knee angle to be either a reliable determinant or reasonable indicator for functional postures.

A common problem for the proper chair fit is seen when the best height is determined to be at the end-range of the chair cylinder excursion. The typical adjustable chair cylinder will position the seat pan from 17-22 inches height. Even when a chair has the right fit and features for the seat and back, if the optimum chair height is off by one- to two-inches, the injured client may not be able to resolve symptoms without good leg support from the floor. The petite client may be require a a shorter chair cylinder with a pan height range from 14-18 inches; and the opposite is true for the taller subject. The user can determine the proper chair cylinder when the tested heights are both clearly above and below the optimum height, i.e., the subject can find the peak height somewhere in the mid-range of the cylinder heights. A more petite person may find the best height is at the very lowest excursion, but that does not prove that the optimal height has yet been determined. There is a need to try a chair with a shorter cylinder excursion if the lowest height seems best, simply to prove the selected height is the peak value. The taller person can explore higher pan heights more easily, using a towel or pad is placed on the seat pan to increase the relative height excursion to include a peak value that lessens as the chair goes to a taller position.

Another common practical problem is caster-floor surface incompatibility: most office chairs are provided with a caster designed for a low-pile carpet typically used in the office. As either the casters or the carpet wears, resistance to movement may increase, and the most common solution is to use a hard-plastic floor pad. Ease of movement is often considered an advantage, but the chair caster/floor surface incompatibility may cause the chair to become unstable and present a fall liability. The chair instability can also be problematic when small movements of the legs move the chair well before the legs can support a change in posture—the unstable chair is then adjusted to minimize the effect of the leg movement just to stay in the chair—ultimately any likelihood of a simple postural correction is lost.

Objective measures were not recorded to correlate the average generated leg strength with subjective choice for the best height. A skilled observer blinded to the particular height measure can identify when the body moves more easily by using observable cues of muscle substitution and acceleration for the chair. Accelerometer measures recording concentric (acceleration) and eccentric (deceleration) muscle contraction at the hip and leg can be used to determine the net forces generated by the legs, provided those forces are averaged and considered as cumulative efforts, i.e., acceleration is recorded as a positive value that reflects as much effort as an equal deceleration force, but the deceleration value is a negative number. Provided the absolute values for acceleration and deceleration are considered in the calculation, the averaged torque can be expressed as force, $F = MA$; where F is the force and M is the mass of the body (essentially unchanged during the test) times acceleration, or A, (expressed as sum of squares or absolute value). A patented application using the accelerometer on a smart phone is called HipTorque™, and is available to measure those values for leg strength in sitting. A corollary method using image translation from video may be an alternative objective measure for acceleration/deceleration values. Regardless of the qualitative measurement technique tested here, an objective measure may be desirable to examine complete reliability for the subjective measures.

Part II. Outcome Measures for the injured office worker:

Two studies were done to clarify the client response to the ActivSeating™ process, and both showed remarkable improvements in the report of symptoms and productivity for the injured office worker. These studies were done in varied office environments in a Fortune 500 company. All of these people had been given an on-line ergonomics training and intervention program, but were referred to the consultant because of worsening symptoms. Many of these people also had continuing medical treatment at the time of the consultation, and may likely have become Workers' Compensation claims.

Testing specific outcomes for the process was complicated in several ways. First, there was extreme variability in the kinds of office work observed, from executive and management positions, financial analysts, traders, call centers, computer support desks, programmers and data entry positions, administrative support positions, loan officers, bank tellers and receptionists. The typical outcome data for these individual ergonomics interventions are not readily available to an outside consultant, so less rigorous methods were needed for any measure of validity.

Almost none of these clients did dedicated and sustained keyboard work, yet almost all had an adjustable keyboard tray and arm. The typical use of the computer was intermittent keyboard and mouse use, combined with other tasks on the work surface, like reference to paper, bound and loose, calculators, written notes, telephone and/or PDA. Almost every client had a full-feature ergonomic chair (Herman-Miller Aeron), and most all had panel-supported, fixed-height modular work surfaces. In most cases the clients used a conventional, reclined chair posture with an adjustable keyboard tray for computer input. Fewer than 20% of the population had free-standing desks or electric height-adjustable work surfaces.

The author was experienced with using the integration process for Workers' Compensation Claims in government agencies, and the ability to follow-up with every case suggested there was ample evidence the methods were sound. Questions remained for how these clients report changes in their symptoms over the longer term with a much larger sample size. Follow-up visits were not possible with this corporate client, so alternative and independent means for outcome measures were needed.

The first test of outcomes was a single-survey design using a follow-up questionnaire sent to 1,000 people that were seen only once for the initial consultation. The survey was provided to clients over a five-year period ending 2015. The subjects were asked to rank their present level of discomfort since the intervention using a 5-point Likert scale (very low, low, moderate, high, very high), and to indicate if those changes made any difference for their productivity using a 7-point Likert scale (much better, better, somewhat better, no change, somewhat worse, worse, much worse). Most (92%) of the 187 respondents (18.7%) reported their symptoms were either "much better," or "somewhat better," and most of the subjects (94%) reported they were more productive (much better, somewhat better, or better). None reported they were worse as a result of the intervention.

The second study was a much more rigorous repeated survey design, taking advantage of a change in the ergonomic report template that asked the client to name the symptomatic body part at the time of the assessment, and then to give a subjective estimate for the frequency and severity of their symptom.

Method:

The symptomatic body part was recorded for each client at the initial ergonomic assessment and that frequency of discomfort was recorded as a 5-point Likert scale (rarely, sometimes, often, frequently, all the time) and the severity was also recorded on a similar scale: (very low, low, moderate, high, very high). 233 people were then given the same questions six to eighteen months after their initial assessment, and a total of 134 people responded (57%), 83 female and 51 male. 80 people reported low back pain as the primary complaint, and 54 people reported primarily upper quarter (neck, shoulder, arm and hand) symptoms. In every case, the follow-up frequency and severity scores were combined and compared with the initial score using a paired samples test.

Observation:
The most typical work patterns included alternating between the two different types of task postures described previously: a) predominantly mixed- and multiple-tasks at the work surface combined with short keyboard entries, editing, calculations and paper collaboration which was considered forward-torso bias work, and b) work that required extended telephone calls, reading content on the monitor and in-hand, and in-person interview which were considered reclined-torso work. The corporate culture tended to maintain the client at the same workstation location for several years at a time.

Intervention:

a) Clients were given instruction and a demonstration of the spine posture correction described previously
b) The consultant made observations for chair fit, and reviewed the chair adjustment features with the client
c) The chair recline resistance was adjusted for the client.
d) Chair height selection was done with the chair locked in level/forward tilt, and the chair transition adjustment from forward to recline postures was demonstrated.
e) The stature of the client was measured in upright sitting
f) The top line of the monitor was calculated with consideration of changes resulting from the type of eyewear and the work surface height tested
g) The client was given examples of work style/bias and postural correction strategies for each
h) Recommendations were provided:
    a. work surface height was indicated for a fixed-height desk; where possible a standing work surface was provided per client request
    b. Keyboard tray deletion
    c. Break-reminder software was provided if indicated by the client work style (executive assistant, receptionist and administrative assistant roles were excluded because of the regular breaks away from the computer)
    d. Alternate chair size if indicated

Follow-up:
Each client was contacted by telephone to repeat the same survey questions initially recorded at the onset. A voicemail was provided if direct contact was not possible, and a follow-up email with the survey questions was provided. The duration from initial consultation to the presentation of the Follow-up survey ranged from six to eighteen months. Raw data was collected on a spreadsheet (Appendix 1.)

Data Management:
The data were entered into an IBM SPSS Statistics program, and calculated for Paired Sample Statistics, and Paired Samples Test.

Results:

The average combined frequency and severity for the Low Back pain group (n = 80) prior to the assessment was 13.31, (standard deviation 8.36) or "moderate-high severity," at the frequency of "regularly-often." These clients reported their average current pain and severity levels after the consultation at 1.96, (standard deviation 1.82) or "very low-low," and "rarely-sometimes." The difference between the initial and follow-up surveys represented a 85.3% reduction in low back pain severity and frequency (p=0.0001).

The results for the Upper Quarter symptoms group (n = 54) showed a similar result: at the initial assessment the discomfort severity and frequency was reported at 11.13, (standard deviation 5.41) or "moderate to high severity," at the frequency of "regularly-often." These clients reported their average current pain and severity levels in the follow-up survey at 2.26, (standard deviation 2.696) or "very low to low," and "rarely to sometimes." The difference between the initial and follow-up surveys represents an 80% reduction in discomfort severity and frequency (p=0.0001) for the group that reported upper quarter disorders.

The two groups combined (n = 134) reported their average discomfort severity and frequency at 12.43, (standard deviation 5.46) or "moderate to high severity," at the frequency of "regularly-often." These clients reported their average current pain and severity levels in the follow-up survey at 2.08, (standard deviation 2.34) or "very low to low," and "rarely to sometimes." The difference between the initial and follow-up surveys represents an 83% reduction in discomfort severity and frequency (p=0.0001) for the total combination of groups that reported low back and upper quarter disorders. There was not a significant difference between men and women. None were worse.

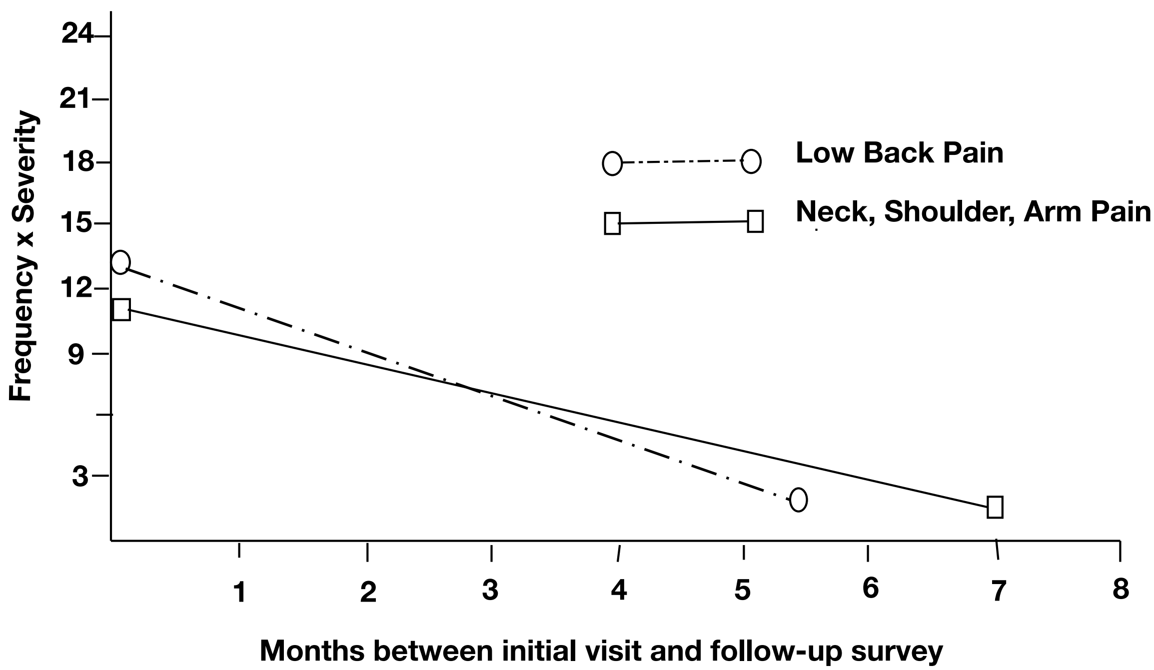

Table 1. Graph of average difference in the initial report of discomfort and the follow-up survey vs. the average time in months between initial visit and follow up. Discomfort was reported as the product of frequency and severity on a 1-5 point scale, with the total severity range from 1-25.

Discussion:
A sample of convenience from regular consulting referrals was used to determine the outcome in symptoms reporting the combined use of the two field measures, and a control group was not considered. The recommendations were adapted to meet the local environment, and most of the subjects were well established in their location, and most expected at least a year in the specified location. Clients who later moved to a new location that did not meet the recommendations were disqualified from the study.

Most of the clients were assigned a fixed-height desk in a panel-supported, modular group of office cubes, although approximately 20% already had height-adjustable tables. All of the clients tested were provided the recommended fixed work surface height for seated work. In some cases, clients were provided a seated corner-diagonal work surface as the primary location for the computer, and if requested, they were also given a standing height at an adjacent return for brief tasks that did not require the computer (paper collation, reading in hand, phone calls). Subjects whose workstation could not be modified were excluded from the study. Surprisingly, clients with existing height-adjustable tables reported similar severity as those with fixed-height surfaces, but that relationship was not examined.

A control group was not considered since the most of the subjects already had prior ergonomic training and intervention: fully adjustable chair, adjustable keyboard tray and in some cases a height-adjustable work surface. The status at the initial assessment was considered a nominal control for later comparison. Further study with a comparison of control and experimental groups in different environments may be indicated to clarify if there are significant differences for those who have completed recommendations and those who have not.

Although the correlation coefficients for the testing method were demonstrated prior to the experiment for the same-day consistency, reasonable variations over the short and long term (time of day, weight change, different shoe height) were not examined. The experimental outcome was expected to be the primary result of integrating the existing chair and work surface, and the effect of any additional products like an ergonomic mouse or keyboard were not considered. Furthermore, presuming there is reliable consistency between observers, any substantive difference in either the kind of recommendations or an outcome difference between consultants was not tested.

The recommendations were made without any instruments apart from a tape measure. A smart-phone application can display the specific leg torque at different chair heights, and is effective to show peak torque values and their decline above and below the optimal height. The subject's demonstrated response for the effort to move the chair at heights above and below the peak value (easiest height) was considered sufficient for the field recommendation. Correlation coefficients comparing subjective data (observation of client effort) and objective data (accelerometer) were not tested.

Different corporate cultures can make a reasonable business case to use full-surface depth electric height-adjustable work surfaces available without a keyboard tray. The engineering services to re-locate a panel supported work surface is not a trivial expense, and if the users are required to regularly move to alternate locations, that service expense can be minimized with an electric height-adjustable table. Fixed-height recommendations seemed to be the most economic solution for this client.

The height of a free-standing desk can be raised in a relatively quick and inexpensive manner using Deskalator kits or Raise-It's desk risers, but lowering a metal or wooden desk clearly requires greater expense (either carpentry, reconstruction or a new desk) that must be considered in terms of the relative cost vs. the value of the injured client's contribution.

Although one specific ergonomic chair was used in this study because it was simply the corporate choice. Fortunately, that chair had the essential features of locking adjustment in forward tilt—a feature which is duplicated in a wide variety of chairs from many different manufacturers. The study does not intend to promote any particular chair design, but does clarify the advantage of chairs with a locking forward tilt option in a population that does a combination of forward and reclined tasks. Those chairs that do not support forward work may be perfectly appropriate for environments that do not require work with the torso forward.

Break-reminder software was shown to have a significant effect for the report of spinal symptoms, and it was used where indicated for those clients who indicated a tendency to sit for more than an hour in sustained postures. Job descriptions that had a variety of tasks in an hour, like administrative/executive assistants, who send and receive documents, do client reception, acquire and distribute office supplies, make short errands for copy, supplies or facsimile, or possibly stand and walk to client interactions away from the desk were not considered for the break-reminder software. That software was not tested for the installation, set-up and effectiveness.

All of the clients demonstrated postural cues to normalize spinal postures, but there was no further attempt to survey their compliance, either at or away from work. The degree to which the clients were compliant with chair adjustment to meet the change in work bias from recline to forward was not examined.

Conclusion:

When the chair and workstation are properly adjusted together for the strength and stature of the body, the worker can move to passive reclined sitting with a simple chair adjustment—and the work surface can stay in the same place. These are not relatively costly changes, and there is extremely low risk. Micro-movements at the spine in neutral postures seem to be the key to healthy sitting. These advantages extend not only for complaints related to spinal problems, but presumably have some effect for the longer-term risk factors for physiologic diseases that can be mitigated with more active spinal postures.

None of the people who completed these recommendations were worse. The extra time and care required to take more sensitive measures of strength and posture appears to be negligible in terms of the assessment process and the desired outcome. The criteria for the chair and work surface integration seems consistent with the principle to fit the workstation to the worker, rather than require every client to work at an arbitrary work surface height.

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Appendix 1. Raw Data from Pre- and Post-consult comparisons

Appendix 2. Paired Samples Test Statistics
Note: These data are presented in the following order:
- 2a. Paired Samples for the Combined Low Back and Upper Quarter, Pre- and Post-Intervention Paired Samples Test of the Difference
- 2b. Separate Group Comparisons, Group 1, Low Back and Group 2, Upper Quarter and the Difference
- 2c. Paired Samples Test by Gender, F = Female, M = Male

Appendix 1.

Raw Data from Pre- and Post-Consult Comparisons

Assessment Date	Male/ Female	Primary Body Part A	Severity (1-5) A	Frequency (1-5) A	Index A (Severity * Frequency	Comments A	First Follow-up Date	Severity (1-5) 2A	Frequency (1-5) 2A	Index 2A (Severity * Frequency)
10/6/2015	F-1	left shoulder	4	5	20	contact	12/16/2015	1	1	1
7/28/2015	F-1	upper back, shoulders	3	4	12	contact	12/16/2015	2	2	4
9/14/2015	F-1	right wrist	5	4	20	contact	12/16/2015	1	1	1
8/5/2015	F-1	right wrist and hand	5	5	25	contact	12/16/2015	2.5	2	5
9/16/2015	F-1	neck	3	5	15	contact	12/16/2015	1	1	1
10/20/2015	M-1	neck	3	3	9	contact	4/28/2016	2	2	4
11/24/2015	F-2	low back	3	3	9	contact	4/28/2016	1	1	1
1/26/2016	F-1	neck	4	5	20	contact	4/28/2016	1	2	2
12/15/2015	F-2	low back	3	3	9	contact	4/28/2016	1	2	2
2/10/2016	F-1	upper back, shoulders	5	4	20	contact	4/28/2016	1	2	2
1/22/2016	F-1	hand	4	4	16	contact		3	2	6
12/15/2015	M-1	neck	3	3	9	contact	4/28/2016	1	1	1
2/19/2016	M-2	low back	4	5	20	contact	8/23/2016	1	1	1
1/6/2016	M-2	low back	3	2	6	contact	8/22/2016	1	1	1
4/20/2016	F-1	neck/shoulder	3	3	9	contact	8/23/2016	1	2	2
6/9/2016	F-1	right wrist, forearm	3	4	12	contact	8/23/2016	1	1	1
2/18/2016	M-1	shoulder	5	3	15	contact	8/23/2016	1	1	1
4/6/2016	F-1	shoulders	5	5	25	contact	8/23/2016	1	1	1
5/11/2016	F-1	right elbow	4	4	16	contact	8/23/2016	3	2	6
4/18/2016	M-2	low back	2	2	4	contact	8/23/2016	1	1	1
2/9/2016	F-1	right shoulder/arm	4	4	16	contact	8/25/2016	1	1	1
3/21/2016	M-2	low back	5	5	25	contact	8/25/2016	1	1	1
4/19/2016	M-2	mid-back	4	4	16	contact	8/25/2016	1	1	1
4/11/2016	F-1	shoulders	3	2	6	contact	8/25/2016	1	1	1
5/17/2016	M-1	wrist pain	3	4	12	contact	8/25/2016	1	1	1
4/12/2016	M-1	left elbow	3	3	9	contact	8/25/2016	1	1	1
5/17/2016	M-2	low back	4	4	16	contact		1	1	1
11/4/2016	F-1	left shoulder	2	2	4	contact	3/3/2017	1	1	1
4/5/2016	F-1	right forearm, hand	4	4	16	contact	3/3/2017	1	1	1
11/2/2015	M-2	low back	3	3	9	contact-call back	4/28/2016	1	2	2
12/15/2016	F-1	right arm	4	5	20	contact-call back	3/3/2017	1	1	1
3/22/2017	M-1	right forearm	3	2	6	conversation	6/14/2018	1	1	1
6/7/2017	F-1	right shoulder, arm	2	2	4	conversation		1	1	1
7/19/2017	M-2	low back	3	4	12	conversation	6/15/2018	1	1	1
5/31/2017	F-1	left shoulder	4	4	16	conversation		1	1	1
9/19/2017	F-1	neck, back	5	4	20	conversation		1	1	1
5/22/2017	F-1	left arm	4	3	12	conversation		1	1	1
2/22/2018	F-2	low back, right forearm	3	3	9	conversation		1	1	1
12/20/2016	F-1	headaches	4	4	16	conversation 6/27/18		1	1	1
8/30/2016	M-1	right elbow	3	2	6	conversation 6/28/18		1	1	1
3/8/2017	M-2	low back	5	1	5	conversation 6/28/18		1	1	1
7/19/2017	F-2	low back	5	5	25	conversation 6/28/18		1	1	1
1/11/2017	M-1	right shoulder	4	4	16	conversation 6/28/18		1	1	1
5/31/2017	M-2	low back	2	2	4	email 6/15	6/15/2018	2	2	4
5/12/2017	F-2	low back	3	3	9	email 6/17		1	1	1
12/26/2016	M-1	neck	2	2	4	email 6/17		1	1	1
12/26/2016	F-1	neck, right shoulder	4	4	16	email 6/17		2	2	4
12/26/2016	M-1	neck	4	4	16	email 6/17		1	1	1
7/25/2017	F-1	neck, back	4	4	16	email 6/27		3	2	6
9/19/2017	F-2	low back	4	4	16	email 6/27		3	4	12
1/17/2016	F-1	left elbow	3	5	15	email 6/27		1	1	1
7/19/2016	F-1	right elbow	3	5	15	email 6/27		1	1	1
11/30/2016	F-1	right shoulder	4	4	16	email 6/27		2	2	4
7/15/2016	M-2	low back	3	3	9	email 6/27		1	1	1
9/6/2017	F-1	neck, right shouder	4	3	12	email 6/27		1	1	1
3/8/2017	F-1	right arm	4	4	16	email 6/28		1	3	3
10/4/2016	F-2	low back	2	3	6	email 6/28		2	2	4
11/3/2016	M-2	low back	3	3	9	email 6/28		1	1	1
11/22/2016	M-2	low back	1	1	1	email 6/28		1	1	1
3/24/2017	F-1	neck	4	3	12	email 6/28		2	2	4
6/30/2017	F-2	back, shoulders	3	3	9	email 6/28		1	1	1
6/30/2017	F-1	right wrist	3	2	6	email 6/28		1	1	1

8/18/2017	F-1	weist, neck, shoulders	3	3	9	email 6/28		1	1	1
3/8/2018	F-1	right wrist, forearm	3	3	9	email 6/28		3	2	6
12/16/2016	F-2	low back	3	3	9	email 6/28		1	1	1
12/31/2016	M-2	legs	4	4	16	email 6/28		1	1	1
8/11/2016	F-1	right arm	4	5	20	email 6/28		1	1	1
9/29/2016	M-1	neck, low back	5	4	20	email 6/28		2	2	4
8/5/2015	F-1	right shoulder	4	4	16	email response	12/16/2015	2	3	6
5/26/2015	F-2	low back	4	4	16	low back	8/24/2015	1	1	1
5/27/2015	F-2	low back	4	2	8	message back	8/24/2015	1	1	1
6/8/2015	M-1	wrist	4	5	20	message back	8/24/2015	1	1	1
6/8/2015	F-2	right hip	3	2	6	neck	8/24/2015	2	1	2
5/19/2015	F-2	low back	3	2	6	new symptom area	8/24/2015	1	1	1
2/6/2018	M-2	low back	3	5	15	no answer/email	6/14/2018	3	3	9
5/19/2015	M-1	left elbow	5	4	20	physical therapy	8/24/2015	3	2	6
1/28/2016	F-2	low back	4	3	12	recheck in 2 months	8/25/2016	2	2	4
2/3/2016	F-1	left wrist	4	5	20	response	8/23/2016	1	1	2
7/13/2015	M-1	neck	2	5	10	returned call	5/6/2016	1	1	1
6/23/2015	F-1	right forearm	3	3	9	right hip	8/24/2015	2	2	4
6/24/2015	F-1	neck	5	3	15	voice mail	8/24/2015	1	2	2
3/23/2016	F-2	low back	4	4	16	voice mail	8/23/2016	3	3	9
5/16/2016	M-2	low back	3	5	15	voice mail	8/25/2016	1	1	1
1/19/2017	F-2	low back	3	4	12	voice mail	3/3/2017	1	1	1
5/5/2016	F-2	low back	5	5	25	voicemail	8/25/2016	4	4	16
6/1/2016	F-1	neck/back/shoulder	3	5	15	voicemail	8/25/2016	1	1	1
4/21/2016	F-1	shoulder	3	4	12	voicemail	8/25/2016	2	5	10
5/4/2016	F-1	shoulders	4	3	12	voicemail	8/25/2016	1	1	1
5/1/2016	M-2	low back, leg	3	3	9	voicemail	8/25/2016	1	1	1
3/4/2016	M-2	low back	3	4	12	voicemail	8/25/2016	2	2	4
5/17/2016	M-2	low back	3	3	9	voicemail	8/25/2016	1	1	1
3/15/2016	F-1	neck	3	3	9	voicemail	8/25/2016	1	1	1
3/29/2016	F-2	right leg	4	1	4	voicemail	8/25/2016	1	1	1
4/4/2016	F-1	headaches	4	3	12	voicemail	8/25/2016	1	1	1
6/6/2016	M-2	left leg	2	3	6	voicemail	3/3/2017	1	2	2
7/11/2016	M-1	left hand	1	2	2	voicemail	3/3/2017	1	1	1
11/2/2016	M-2	low back	3	2	6	voicemail	3/3/2017	1	1	1
11/18/2016	M-2	low back	4	5	20	voicemail	3/3/2017	1	1	1
3/1/2016	M-1	hands	4	5	20	voicemail	3/3/2017	1	1	1
9/2/2016	F-1	neck	4	5	20	voicemail	3/3/2017	1	1	1
12/1/2016	M-2	legs	3	3	9	voicemail	3/3/2017	3	2	6
1/23/2017	M-2	low back	4	2	8	voicemail	3/3/2017	1	1	1
7/7/2016	M-2	mid- low-back	3	4	12	voicemail	3/3/2017	1	1	1
7/11/2016	M-1	right forearm	3	4	12	voicemail	3/3/2017	1	1	1
8/18/2016	M-2	low back	3	3	9	voicemail	3/3/2017	1	1	1
9/9/2016	F-1	neck, right arm	4	5	20	voicemail	3/3/2017	1	1	1
10/5/2016	F-1	neck	2	3	6	voicemail	3/3/2017	1	1	1
10/27/2016	M-1	neck	3	3	9	voicemail	3/3/2017	1	1	1
11/7/2016	F-1	right elbow	3	3	9	voicemail	3/3/2017	1	1	1
12/19/2016	M-2	low back	4	4	16	voicemail	3/3/2017	1	1	1
3/1/2016	M-1	neck	3	3	9	voicemail	3/3/2017	1	1	1
6/22/2016	F-1	neck	4	4	16	voicemail	3/3/2017	1	1	1
6/28/2016	F-1	neck	4	4	16	voicemail	8/25/2016	1	1	1
7/26/2016	F-1	neck, right arm	5	3	15	voicemail	3/3/2017	1	1	1
6/7/2017	F-2	low back	3	2	6	voicemail, email 6/15	6/15/2018	1	2	2
5/31/2017	F-1	neck, shoulder	1	2	2	voicemail, email 6/15		1	1	1
11/17/2016	M-1	hands	3	3	9	voicemail, email 6/15	6/15/2018	1	1	1
8/1/2016	F-1	neck/shoulder	4	3	12	voicemail/email	6/14/2018	1	1	1
4/6/2015	M-1	neck/shoulder	3	3	9		8/24/2015	1	1	1
4/6/2015	F-2	low back	4	2	8		8/24/2015	2	1	2
4/15/2015	F-2	low back	3	3	9		8/24/2015	1	1	1
3/15/2016	M-2	low back	4	4	16		8/25/2016	2	2	4
12/7/2016	F-2	low back, neck	5	3	15		3/3/2017	1	1	1
7/21/2017	M-2	low back	4	3	12		6/14/2018	1	1	1
10/7/2016	F-2	low back	4	3	12		6/14/2018	1	1	1
3/22/2017	F-1	right shoulder, head	3	3	9		6/14/2018	1	1	1
5/17/2017	F-1	neck, right shoulder	4	5	20		6/15/2018	1	1	1
8/21/2017	F-1	right shoulder	4	5	20		email 7/11/18	1	1	1
7/28/2017	F-2	mid-back	3	3	9		email 7/12/18	1	1	1
7/12/2017	F-1	right wrist	3	3	9		email 7/12/18	2	2	4

5/11/2017	F-1	left hand	3	3	9		email 7/12/18	1	1	1
3/20/2017	F-1	right shoulder	3	3	9		email 7/12/18	2	2	4
2/5/2018	M-2	low back	5	2	10		email 6/19	1	1	1
4/12/2016	F-1	neck, right forearm and hand	3	3	9		email 7/19	1	1	1

Appendix 2a.

Paired Samples Test Statistics

Paired Samples for the Combined Low Back and Upper Quarter, Pre- and Post-Intervention, Paired Sample Test of the Difference

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Index A (Severity * Frequency	12.43	134	5.463	0.472
	Index 2A (Severity * Frequency)	2.08	134	2.343	0.202

Paired Samples Test

		mean	standard deviaion	standard error of the mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Index A (Severity * Frequency - Index 2A (Severity * Frequency)	10.351	5.469	0.472	9.416	11.285	21.907	133	0.000

Appendix 2b.

Paired Samples Test Statistics

Separate Group comparisons, Group 1, Low Back and Group 2, Upper Quarter and the Difference

Paired Samples Statistics

group			Mean	N	Std. Deviation	Std. Error Mean
1: Low Back	Pair 1	Index A (Severity * Frequency	13.31	80	5.355	0.599
		Index 2A (Severity * Frequency)	1.96	80	1.824	0.204
2: Upper Quarter	Pair 1	Index A (Severity * Frequency	11.13	54	5.408	0.736
		Index 2A (Severity * Frequency)	2.26	54	2.960	0.403

Paired Samples Test

			mean	standard deviation	Standard error of the mean	Lower bound of estimate	Upper bound of estimate	t	df	Sig. (2-tailed)
1: Low Back	Pair 1	Index A (Severity * Frequency - Index 2A (Severity * Frequency)	11.350	5.429	0.607	10.142	12.558	18.700	79	0.000
2: Upper Quarter	Pair 1	Index A (Severity * Frequency - Index 2A (Severity * Frequency)	8.870	5.234	0.712	7.442	10.299	12.453	53	0.000

Appendix 2c.

Paired Samples Test Statistics

Paired Samples Test by Gender,

F = Female, M = Male

Paired Samples Statistics

gender			Mean	N	Std. Deviation	Std. Error Mean
F	Pair 1	Index A (Severity * Frequency	13.11	83	5.419	0.595
		Index 2A (Severity * Frequency)	2.33	83	2.660	0.292
M	Pair 1	Index A (Severity * Frequency	11.33	51	5.406	0.757
		Index 2A (Severity * Frequency)	1.69	51	1.655	0.232

Paired Samples Test

gender			mean	standard deviation	Standard error of the mean	Lower bound of estimate	Upper bound of estimate	t	df	Sig. (2-tailed)
F	Pair 1	Index A (Severity * Frequency - Index 2A (Severity * Frequency)	10.783	5.491	0.603	9.584	11.982	17.892	82	0.000
M	Pair 1	Index A (Severity * Frequency - Index 2A (Severity * Frequency)	9.647	5.414	0.758	8.124	11.170	12.725	50	0.000