Humanics ErgoSystems, Inc.

Specialists in Ergonomics

REVIEW: ARMREST DESIGN AND USE

Rani Lueder, CPE and Paul Allie

For Steelcase Furniture

July 26, 2003

Certificant, Board of Certification of Professional Ergonomists

Mail: P.O. Box 17388 Encino, CA 91416-7388
Phone: (818) 345-3746 (ERGO) **Email**: ergonomics@humanics-es.com **Web**: www.humanics-es.com

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Overview

It is difficult to grasp how dramatically seating has changed over recent decades. The standard secretarial chair in the 1950's provided seat and backrest height adjustment, and little else. Typically, these chairs afforded minimal low back support and no relief for the upper back and arms.

Armrests were generally not recommended for typists (Lundervold, 1951). Manager often garnered armrests as status symbols. However, even the most successful executive could not adjust these supports.

Seating and postural arm supports have more recently come under intensive scrutiny. Research since the early 1980's indicates that not only computer users experience high rates of physical discomfort; general office workers are often much more uncomfortable than had been presumed. Further, recorded rates of soft tissue disorders referred to as Cumulative Trauma Disorders (CTDs) have increased more than thirteen-fold since 1982 (Bureau of Labor Statistics, 1996a, 1996b).

From another front, international competition spurred an interest in how ergonomic seating and improved postural support can improve productivity. Workers have changed as well; they now expect to participate in their working conditions, and for many, a comfortable chair ranks high on their list[1].

What causes work-related injuries?

Musculoskeletal disorders result from physical stresses that exceed the ability of the body to withstand them without harm. Local muscle fatigue is often a precursor of these disorders (Baidya and Stevenson, 1985 and 1988; Blader et al, 1991; Buckle, 1988; Hagberg et al., 1995; Jensen et al, 1993; Pheasant, 1991; Rempel et al, 1992; Sommerich et al., 1993) as well as muscle spasms and tremor (Pheasant, 1991).

Such disorders commonly result from the cumulative and sustained nature of exposures over time. Cumulative effects of such musculoskeletal demands contribute to a variety of chronic impairments and pain (Grandjean, 1987; Kilbom, 1987). Pain and discomfort may be specific or experienced as a chronic generalized pain, with multiple tender "trigger" points (Pheasant, 1991).

It is generally believed that the primary CTD risk factors include static postures, awkward positions, and excessive levels of force, pressure and/or repetition… or not infrequently the combination of these events (Sommerich et al., 1993; U.S. Dept. of Public Health and Human Services, 1997). Although such disorders are not new (*s.f.* Ferguson, 1971; Duncan and Ferguson, 1974), these risk factors have become increasingly prevalent with today's computer workplaces (*s.f.* Stack, 1987; Waersted and Westgaard, 1997).

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[1] Further, Sauter (1983) found that perceived chair comfort was the second strongest predictor of back, neck and shoulder discomfort.

How do armrests fit in the scheme of things?

A good seat should support a variety of postures to allow the user to be comfortable and to work effectively. Many factors affect armrest usage, including the task (Gangloff et al, 1984) and the design of the chair (Branton and Grayson, 1967).

Armrests must also accommodate a very diverse range of users and task requirements. Females sit more upright than males (e.g., Branton and Grayson, 1967; Floyd and Ward, 1964, Le Carpentier, 1969; Ridder, 1959). There seem to be individual patterns of sitting behavior, perhaps based on motor patterns (Fleischer et al, 1987).

Interestingly, Rose (1991) recommended that when arms are supported while keying, key forces are reduced[2]. Michael Feuerstein (1995) recently found that workers engaged in word processing type with excessive force and that those with greater levels of musculoskeletal symptoms strike the keys significantly harder.

Whether used intermittently or continuously, armrests are an important form of postural support. Further, new designs and approaches continue to be introduced in the market.

The writers were therefore surprised that there did not appear to be any specific overviews on the topic. This review was written as an attempt to fill this void. Correspondingly, the functions and basis for proper armrest designs are described below.

1. Armrests reduce loads on the neck, shoulders and arms

Neck/shoulder discomfort and pain is common among computer users (Camerino et al, 1995; Hagberg and Wegman, 1987[3]; Hunting et al, 1981; Ryan and Bampton, 1988[4]). These discomforts may be caused by a variety of factors, including the arm support.

The primary role of the shoulder girdle is to suspend the arms (Hagberg, 1981a). Such postures are common at work; as Berbuer (1985) notes, in order to work "the whole weight of the hands, forearms and upper arms must be held forward of the trunk, giving rise to a considerable amount of force of rotation in the shoulder joints". Maintaining arms elevated to the side (abducted) magnifies these loads further (Hagberg, 1981; Hansson et al, 1992, US Public Health Service, 1997).

Of particular interest regarding static loads associated with awkward arm postures is the load acting on the trapezius[5] (Fernstrom and Ericson, 1996; Hagberg, 1981; Hagberg

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[2] Key activation forces of .7 N were recommended when users keyed with supported arms, compared with 1.1 N key forces without arm support.

[3] These researchers found that keyboard operators had an odds ratio of 3:0 for developing "tension neck syndrome".

[4] Based on interviews, Ryan and Bampton (1988) report that this disorder is characterized by an "ache, with a tense, or pulling quality in the extensor muscles of the forearm… Typically, the ache or pain slowly increased in frequency, duration, and intensity, until it occurred daily, lasting after work into the evening, or even longer. There was often an accompanying feeling of weakness or heaviness in the hand and arms. The ache in the shoulder or neck appeared to be different in quality, did not radiate, nor was there any feeling of weakness as in the hand and arm."

and Sundelin, 1986; Hansson et al, 1992; Waersted and Westgaard, 1997), a kite-shaped muscle that triangulates between the neck, shoulder and spine - as well as the supraspinatus, deltoid and rotator cuff muscles. Rempel et al. (1992) reports that tension neck syndrome, characterized by pain and tenderness in the neck and shoulders and a hardening of the trapezius is common among people that must perform static postures and repetitive work requiring sustained abduction or extension of the upper arms.

Research indicates that excessive demands on these muscles contribute to CTDs of the neck and shoulder[6] (Aaras, 1990a; Aaras, 1990b; Aaras, 1994; Kilbom and Persson, 1987; Sauter et al, 1984), reduced endurance times (Hansson et al, 1992) and impaired range of shoulder motion (Hagberg, 1996; Hagberg and Kvarnstrom, 1984; Sommerich et al, 1993).

The adverse effect of awkward arm postures are magnified when postures are constrained (Kilbom, 1987). The interruption of blood flow with static postures is increased in proportion to the forces acting by the muscle. When working with continuously elevated arms (at 60% of maximal force), blood flow is virtually occluded (Grandjean, 1987).

Arndt (1983) reported that without arm support "extending the arm forward by as little as 4 inches can accelerate the time to reach fatigue by a factor of 2, and an extension of 8 inches can result in substantial fatigue in less than 10 minutes. Arm or elbow rests extend these times [to reach fatigue] considerably."

Hagberg (1984) suggested that continuous working with elevated and unsupported arms "may accelerate degeneration of shoulder tendons through impairment of circulation[7]". These static loads are independent of muscle strength (Jensen et al, 1993).

Working with unsupported or elevated arms increases the load on the neck, shoulder and back (Aaras, 1990a; Aaras, 1990b; Aaras, 1994; Aaras et al., 1995; Aaras and Ro, 1997; Andersson, 1980; Andersson et al, 1975, 1978 and 1986; Andersson and Ortengren, 1974; Jorgensen et al., 1989; Melin, 1987; Pheasant, 1997; Weber et al, 1984). These static loads are particularly pronounced when sitting (rather than standing), and when working without forearm support (Aaras et al, 1995; Aaras and Ro, 1997).

Lack of arm support is a predictor of developing musculo-skeletal disorders (Bergqvist et al., 1995a and 1995b). The associated demands on the neck and shoulder contribute to pain and discomfort (Kilbom, 1988).

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[5] This is not to suggest that the trapezius is the only muscle involved with these disorders, nor that adverse effects of elevated or abducted arms are specific to the Trapezius muscle. Rather, a complex of muscles come into play when users assume awkward arm postures, and the complex of these muscles contribute to symptoms and disorders. See US Public Health Service (1997) for a review of these issues.

[6] Aaras (1990a) found that risk of musculo-skeletal illness increased when loads on the m. trapezius muscle exceeded 5% of maximal voluntary contraction (MVC). Aaras (1990b; 1994) found a relationship between loads on this muscle and sick leave and pain; further, when forearm support was provided to a group of 20 computer users, pain was reduced (Aaras and Ro 1997).

[7] He noted that "static tension and humeral compression against the coraco-acromial arch" cause this impairment of circulation.

An important means of alleviating such static loads is with intermittent support of the arms. Hunting et al. (1981) showed that reports of "hands and arms frequently supported" was significantly correlated with reduced pain in the neck, shoulders and arms. Arndt (1983) maintained that the presence of an arm support was more important than the actual position of the arms.

Arm supports reduce loads on the trapezius and related muscles (Bendix et al, 1985; Ekholm et al, 1986[8]; Erdilyi et al, 1988; Jarvholm et al., 1991; Melin, 1987; Milerad and Ericson, 1994[9]; Paul et al, 1996[10]; Schuldt et al, 1987; Schuldt, 1988a and 1988b; Sihvonen et al, 1989[11]; Weber et al., 1984[12]) and shoulder pain (Aaras et al, 1995; Aaras and Ro, 1997; Tuvesson et al, 1990). When support is not available, users are more likely to lean their forearms on the desk[13] (Grandjean et al., 1983)

Arm support and sitting posture

Given the physical demands associated with sustaining unsupported arms, it is not surprising that people place first priority on adjusting their seat to afford a comfortable arm position[14,15] (Burandt and Grandjean, 1963; Hunting et al, 1980 and 1981).

This priority takes place even when foot support is sacrificed. Langdon (1965) described the awkward postures that users assume while trying to attain a comfortable working arm posture:

> *"In consequence, although the chair is raised to the point where the limbs cannot be accommodated beneath the desk and the feet cannot reach the floor, the operator is well above the keyboard and sits on the edge of the chair, gripping the curved feet of the chair frame with her shoes".*

Arm support becomes particularly critical when users are unable to adjust their seats high enough to afford a comfortable working arm position. Hunting et al. (1981) report:

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[8] Muscle activity was reduced for both the trapezius and erector spinae.

[9] It is interesting that arm support, but not hand support resulted in a significant reduction of loads of the three primary shoulder muscles (trapezius, supraspinatus, and anterior deltoid).

[10] These researchers found reduced muscle loads with adjustable height armrests during keyboard operation. During mouse use height, loads were reduced with flexible motion of arms that also adjusted in height.

[11] Muscle activity was reduced for both the trapezius as well as the frontalis muscles.

[12] These researchers described the support only as a "forearm-wrist" support. No other information is available on the nature of this device.

[13] This study did not appear to provide armrests; instead they referred to forearm/wrist support without further description.

[14] Typically, users sit between 27 and 30 cm (11 to 12 in.) below the work surface so that their arms are approximately level with their work area.

[15] This is why, at a standard height desk smaller people actually sit higher than their taller counterparts (Burandt and Grandjean, 1963; Floyd and Roberts, 1958; Floyd and Ward, 1964; Langdon, 1965; Lueder 1986a).

"The result is clear: the higher the keyboard, the more frequently hands and arms were supported".

Site and type of hand-wrist or arm support:

When comparing different kinds of arm and forearm support, Wells et al. (1997) found that armrest-supported elbows minimized muscle loads[16] relative to other arm support conditions[17],[18].

Feng et al. (1997) found that all kinds of arm supports (fixed, horizontal and spring-loaded) reduced EMG levels of the shoulder muscles, but the horizontal movable support was most effective in reducing shoulder EMGs when tasks were set at table height.

However, such findings have not been consistent; one study comparing muscle efforts associated with[19] different armrest conditions[20] could not discriminate between types of arm support (Milerad and Ericson, 1994). Helander and Zhang (1997) reported that short subjects found pivoting armrests of one manufacturer were too long, and interfered with their work. Using video analysis of users typing with conventional keyboards Hedge and Powers (1995) found that one armrest model (they described as "full motion forearm supports", or FMFS) made by one manufacturer exerted no effect on wrist angle; this contrasted with typing with a negative slope keyboard system (NSKS), which was found to reduce wrist angles.

2. Armrests reduce loads on the back

Arm supports reduce loads on the spine (Andersson et al., 1975; Andersson, 1980; Aaras et al., 1995). Ericson and Goldie (1989) studied the amount of shrinkage of the spine[21] associated with different seat features, finding that the benefits of an armrest were equivalent to the benefits associated with a forward sloping seat.

Proper armrests can prevent a slumped posture of the upper trunk (Gibson and Wilkins, 1975) and allow users to sit with greater trunk inclination (Nakaseko, 1985).

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[16] Trapezius and infraspinatus of the shoulder as well as the forearm muscles.

[17] Approaches that were evaluated include 1) supporting the elbow on the chair armrest; 2) supporting the forearm on the work surface; 3) working with arms unsupported and 4) planting the outer area of the wrist on the work surface.

[18] **A separate consideration, currently of considerable interest is Carpal Tunnel Pressure (CTP). Carpal Tunnel Pressures among palm rest users have not been found to be lower than those resting forearms on the desk (Horie et al, 1993). Fernstrom et al (1994) found that using a palm rest did not result in decreased EMGs of the forearm and shoulder muscles.**

[19] Muscle groups involved were the trapezius, supraspinatus, and anterior deltoid.

[20] These conditions were working with 1) adjusted elbow support; 2) height-adjusted wrist support; and 3) unsupported hand and arm.

[21] Shrinkage of the spine is considered an index of compressive loads on the spine.

On the other hand, excessively high armrests cause users to hunch their shoulders, thereby contributing to loading on the neck/shoulder and back. Armrests that are too low contribute to slouching and asymmetrical positions, which place demands on the spine. Armrests that are inflexible, poorly designed or interfere with proper positioning in front of the work surface force the user to assume a variety of poor postures.

3. Hand/arm pain may also be referred from the neck/shoulders

The intricate linkages along the hand-arm-shoulder-neck complicate ergonomics assessments. Analysis of causes of disorders is complicated because symptoms may be experienced at a different site than the source of the pain (Kendall, 1960; Gunn and Milbrandt, 1976). Pheasant (1991) described some possible mechanisms for referred pain.

The “Double Crush” phenomenon[22] suggests that “one area of nerve compression may render a nerve more susceptible to symptomatic compression at a second site” (Batzdorf, 1995; Bland, 1995; Osterman, 1988; Sucher, 1995; Upton, 1973). For example, due to a change in nerve threshold, risk factors that contribute to neural damage caused by improper postural support closer to spine (at the cervical root) may as a secondary effect result in referred disorders of the elbow or hand/wrist area.

Bendix and Jessen (1986) emphasized the importance of providing forearm supports for keyboard workers who complain of neck/shoulder pain, underscoring the interactive nature of the neck/arm/wrist linkages.

4. Armrests reduce seat pressures

Armrests reduce forces on the seat by supporting a portion of the weight of the upper torso (Gilsdorf et al, 1991). Branton (1969) described seat pressure findings of Swearingen et al. (1962) indicating that 12.4% of the body weight of seated individuals is borne by the armrests. Research on wheelchair use indicates that transferring the upper body weight to the armrest can reduce seat pressures at the ischial tuberosities (at the seat bones) by 25 to 30% (Andersson et al., 1978).

Armrests that adjust in height, width and pivot have been found to support more of the arms’ weight than designs that only adjust in height and pivot, or provide only height and width controls (In-house Steelcase research, 1997).

5. Armrests also reduce loads on the knees and hips

Rising from a seat places considerable forces acting on the knees and hips (Kelley et al, 1976; Seedhom and Terayama 1976; Rodosky et al. 1989), particularly (while rising) at loss of seat contact (Burdett et al, 1985). This effect creates loads on the knee and hip joints

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[22] This phenomenon is recognized among many experts in the field. For example, 11 of 15 medical specialists presenting at a medical Symposium specifically referred to the Double Crush Phenomenon as a contributor to Repetitive Injuries. (The RSI Symposium; The First International Conference on the Neurovascular Compressions and Cumulative Trauma disorders of the Upper Extremity, 1995).

that compare with going up and down stairs (Andriacchi et al, 1980; see also Seedhom and Terayama, 1976[23]). It is therefore not surprising that older people and those with infirmities report that the most important factor when choosing a chair (more important than comfort) was ease of getting out of it (Munton et al., 1981)[24].

The added support of rising with the arms reduces the mean maximum hip moment by about 50%. The demands on the knees are considerably reduced when rising with the arms, and using armrests (Arborelius et al, 1992; Burdett et al, 1985; Seedhom and Terayama, 1976).

6. Armrests stabilize posture, and appear to increase productivity

Many computer tasks are characterized by static loading of the arms in awkward positions (*s.f.* Waersted and Westgaard, 1997). Mouse usage, for example, is frequently characterized by sustained work with arms extended (Armstrong et al, 1994; Feng et al, 1997), wrists bent more than 15° to the side (ulnar deviation) and shoulders flexed and rotated outward[25] (Karlqvist et al, 1994). This underscores the importance of flexible armrests that readily adjust in height and width, and allow the user to change positions readily as needed to support their work.

Parsons (1991) observed that many users prefer padded chair armrests to palm rests in order to promote free arm motion (palm rests constrain hand positions).

People make fewer errors when their keyboard height is set at "about the right height" (Cushman, 1984). Given the heightened incidence of discomfort and pain associated with performing intensive computer use with unsupported arms (described above), it is reasonable that properly designed armrests may increase productivity.

Armrest design considerations

1. Support a variety of arm positions

Musculoskeletal symptoms are considerably more pronounced on the right side of the neck, arm and shoulder (Hunting et al, 1980 and 1981; Ryan and Bampton, 1988). These lateral differences in discomfort are becoming more pronounced with the introduction of mice and other input devices. It is desirable for arm rests to be flexible to accommodate such asymmetrical postures.

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[23] Robertshaw et al. (1986) did not find this effect, however when comparing users rising with or without hand support, and with different hand placements.

[24] It should be noted that infirmities are not only a function of age. Most of us will develop some degree of disability at some time in our life, such as with sprained ankles, arthritis, pregnancy, or other health considerations. For such users, ease of rising from a chair takes on particular relevance.

[25] This posture is in part caused by postural constraints of the workstations.

2. Pivoting armrests

Properly designed armrests that pivot are appropriate for some applications:

1. Independent pivoting action helps accommodate asymmetrical arm postures (shoulder abduction[26]) commonly found among those working at keyboards (Hunting et al., 1980 and 1981; Serina et al, 1994) and/or using a mouse (Armstrong et al, 1994; Feng et al, 1997; Karlqvist et al, 1994). Typically, these computer users work with the right arm more abducted than the left.
2. Certain specific workstation configurations may interfere with armrests, contributing to adverse working postures. In particular, narrow diameter corner work surfaces may obstruct seat armrests, and force users to work with excessively elevated arms. Adjustments that enable armrests to angle inward reduce the potential for this problem.
3. Pivoting armrests allow users to support their arms while working with a wider range of postures.
4. Computer users' arms hang more naturally near the abdomen when arm caps adjust for both width and angle. Abduction is reduced if the arm cap can be placed directly under the elbow, where it hangs naturally

3. Accommodate users with arm height and width controls

There has been an increasing recognition of the importance of adjustable height armrests for accommodating intensive computer users.

Postures that are symmetrical and supported are generally considered superior. The position of armrests should allow users to sit with arms supported in a comfortable upright position.

Seat height and armrest width control help accommodate different size users' working postures.

Armrest height adjustment range: from 7 to 10.75 inches would accommodate the spectrum of users from 5th percentile female to 95th percentile male (US Army Natick, 1989)

Seat width adjustment range: to accommodate the 5th to 95th percentile dimension, the arms should adjust considerably farther out approximately 4 inches. (US Army Natick, 1989)

4. Stabilize postures

Today's computer users frequently perform intensive computer work requiring high precision, such as while using input devices. Such precise motions may increase the risk of CTDs (Milerad and Ericson, 1994). These users are in particular need of supports that provide postural stability.

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[26] Placing the upper arm at the shoulder to the side, away from the body, as if reaching to one side.

Does not interfere with getting close to the work surface

The optimum length of the armrest depends on the specific configuration and placement of the arms on the chair.

However, under all circumstances, the design of the armrest should not interfere with proper seated postures at the work surface. Poorly designed armrests may constrain postures, causing users to hunch forward and work with elevated arms.

5. Avoid sharp edges

Compressive forces from leaning against sharp edges can injure the soft tissues, in large part by impairing microcirculation surrounding the nerves, and from the direct impact of mechanical forces (Szabo, R.M. and Gelberman, 1987). For example, Sauter et al. (1987) reported that a keyboard worker developed lesions from resting wrists on the sharp edge of the keyboard. "Cubital Tunnel Syndrome" may be caused by external mechanical pressure from resting elbows on hard surfaces (Rempel et al., 1992).

Armrests should be broad and padded, and support the "fleshy" portion of the forearm. These supports should be designed so that they do not impact the highly sensitive ulnar nerve near the elbow (Pheasant, 1997).

Pheasant (1997) recommended that the seat arms include a gap of about 4 inches between the armrest and seat back to avoid the impacting the elbows.

6. Ease of adjustment

Considerable evidence exists that users frequently do not adjust their chairs (e.g., Kleeman and Prunier, 1980; Lueder 1983 and 1995; Shute and Star, 1984; Stewart, 1980; Webb, Tack and McIlroy, 1984). Lueder (1983) reported from her survey that supervisors generally perceived that employees do not know that their seating adjusts.

Certainly, seat design has improved considerably since those early years. Further, employees are increasingly prone to adjust their seating. However, such findings underscore that adjustability alone does not suffice. People must be aware that their chair adjusts. They must also know why it is important to perform the adjustments. Further, adjustments must be easy to use or they will not bother.

Helander et al (1995) described the following essential stages of search and information processing associated with locating and performing adjustments:

> *1. The user first <u>searches</u> for a control. Easily discernible controls will be found first.*
>
> *2. When a control has been found, the user will try to <u>identify</u> the mode of operation, most likely by trial-and-error based on feedback from activating the control.*
>
> *3. After the mode of operation has been identified, the user may adjust the chair to the desired position. Control movements that in some way are compatible with the controlled element are easier to adjust.*

> *Successful adjustment hence requires successful completion of all three steps. An attempt at adjustment may terminate at any of the three different stages owing to poor discernibility of the control, lack of control feedback, and incompatible or vague control response.*

In their subsequent factor analysis of factors associated with ease of adjustment, Helander et al (1995) found that 'discernibility' and 'feedback' represented important criteria of adjustment controls that are easy to use.

Similarly, Lueder (1983, 1995) provided the following design guidelines for ease of adjustment:

a) Features adjust from the standard seated work position.
b) Controls are easy to detect; functions are self-evident.
c) Adjustment results in immediate feedback on the setting.
d) Adjustment is logical, consistent, and follows user stereotypes.
e) A minimum of motions is required and little effort.

Number and kinds of adjustments:

Helander et al (1995) reported that the number of adjustments did not adversely affect perceived ease of use. Further, these researchers found that the armrest that was rated the easiest to adjust in height was adjusted… *"By holding on to the end of the armrests and pushing a control button located immediately under the armrest. At the same time, the armrest could be easily raised or lowered using one hand."*

7. Training

Training in proper seat adjustment is an important provision. Ryan and Bampton (1988) found that individuals with high upper limb symptom scores were significantly less likely to have received training in adjustment of their seat.

Helander et al (1995) noted that training was particularly crucial when the seat was poorly designed.

It is not enough to train users in how to adjust the seat; they must also be taught why they should do so, and receive hands-on instruction (Dainoff, 1984).

Conclusion

The above research demonstrates that armrests serve an important function in promoting comfort and well being and in supporting the work process.

Armrests have been shown to improve posture and promote freedom of movement while stabilizing one’s position; reduce the muscle loads on the neck, shoulders and arms; reduce pressures on the spine; distribute pressures on the seat, support rising and sitting in the chair, and support task-related movements.

Evidence is emerging that computer users’ arms are more appropriately supported when an adjustable armrest can follow task-related postures and arm positions. The more degrees of adjustment employed by an armrest, the more realistically it can be positioned to support users' arms.

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