

EFFECT OF A BACK BELT ON REACHING POSTURES

Dean L. Smith, DC,^a Marvin J. Dainoff, PhD,^b Leonard S. Mark, PhD,^b Shawn P. Oates,^b Niles C. Davis^b

ABSTRACT

Objective: The present study investigated the effect of a back belt on reach actions.

Subjects: Sixteen undergraduate college students (8 male students, 8 female students) ranging in age from 18 to 22 years. Thirteen subjects were included in the final analysis.

Setting: The Department of Psychology at Miami University, Oxford, Ohio

Methods: Using a well-established set of procedures developed in our laboratory for studying reaching, seated adult participants reached for and retrieved an object placed at various distances from them. Reach distances included values both closer than and farther than each subject's maximum seated reach. The reach task had 2 conditions: picking up and retrieving a small block and skewering and retrieving a small bead with a needle. For each task condition, each subject either wore the belt or did not use a belt.

Results: Results indicate that when subjects wore the belt while reaching, they tended to have initial transition points (sitting to nonsitting) closer to their bodies than while not wearing the belt. That is, for a distant object, subjects were more likely to raise their bodies out of the chair rather than perform an extreme seated reach, possibly acting to preserve a greater margin of safety.

Conclusions: The back belt consistently modified reaching postures by limiting extreme ranges of motion during a task that required enhanced stability. Furthermore, the methodology and analysis presented in this article when applied to chiropractic will allow us to begin thoughtful investigation of the effects of chiropractic adjustments on postural transitions and margin of safety. (*J Manipulative Physiol Ther* 2004;27:186-96)

Key Indexing Terms: *Posture; Back Belt; Ergonomics; Chiropractic; Coordination*

INTRODUCTION

Multiple lines of research into the effectiveness of back belts as personal protective devices have yielded conflicting evidence as to the advantages and disadvantages associated with their use. More recent reviews of the literature have not departed markedly from these conclusions¹⁻³ and, additionally, have illustrated the lively debate on the use of abdominal belts in industrial settings.^{2,3} These studies include both field and laboratory research, belts ranging from elastic to full-blown molded

casts, sample sizes from a few to thousands, dependent variables including biomechanical measures (electromyography [EMG],⁴⁻⁸ intra-abdominal pressure,^{6,9,10} spinal shrinkage,⁷ sacroiliac joint shear,¹¹ bending moments,^{12,13} posture,⁵ strength,¹⁴⁻¹⁶ kinematic variables¹⁷⁻¹⁹), physiological measures (e.g., heart rate and blood pressure),^{20,21} psychophysical measures (perceived heaviness of imposed weights,²² subjective enhanced lifting capacity,⁷ willingness to use more weight),²³ and various activities employed (bending,^{17,24} lifting,^{20,25} pulling,²⁶ sitting and slump sitting,^{5,27} standing,^{5,27} and working^{24,26,28}). While a few studies have found minor improvement in lifting capacity with the use of belts,¹⁵ the majority of evidence indicates that belts do not improve muscular strength^{25,26} or fatigue.^{16,25}

As the reader might expect, with conflicting evidence as mentioned above, the use of back belts to prevent musculoskeletal injuries has been controversial. The National Institute of Occupational Safety and Health²⁹ conducted a literature review in which they concluded:

"...the effectiveness of using back belts to lessen the risk of back injury among uninjured workers remains unproven. . .there is insufficient evidence indicating that typical industrial back belts significantly reduce the biomechanical loading of the trunk

^aCenter for Ergonomic Research, Department of Psychology, Miami University, Oxford, Ohio, Private practice of chiropractic, Eaton, Ohio.

^bCenter for Ergonomic Research, Department of Psychology, Miami University, Oxford, Ohio.

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Submit requests for prints to: Dean L. Smith, DC, MSc, Essence of Wellness Chiropractic Center, 890 South Barron St. (PO Box 333) Eaton, OH 45320 (e-mail: drdean@essenceofwellness.com).

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during manual lifting. . . back belts do not mitigate the hazards to workers posed by repeated lifting, pushing, pulling, twisting and bending.”^{29(p1,2)}

Similar sentiments have been expressed by the Agency for Health Care Policy and Research,³⁰ which concluded that “. . . there is no evidence that lumbar corsets or support belts are effective for treating acute low back problems and conflicting evidence on whether lumbar corsets and support belts are effective for preventing or reducing the impact of low back problems in subjects who do frequent lifting at work.”

Cholewicki et al.⁶ cite several papers that indicate abdominal belts are widely prescribed in both industry and rehabilitation without a convincing scientific justification of their benefits. The source of claims supporting the use of support belts to reduce injury have been both from an injury prevention and/or rehabilitation perspective.

Thus, it appears then that the use of lumbar belts in industrial settings continues to be widely debated.

Although previous work has not provided conclusive evidence for the efficacy of back belts, McGill^{3(p1353)} has identified a number of possible effects that back belts might have. The following proposed mechanisms of back belts could provide the basis for future research in delineating any beneficial effects:

1. Reminder to lift properly
2. Support shear loading on spine
3. Compressive load reduced through increased intra-abdominal pressure (IAP)
4. Reduction of range of motion (splint)
5. Providing warmth to the lumbar region
6. Enhancing proprioception via pressure to increase the perception of stability
7. Reducing muscular fatigue

McGill³ indicated that strong evidence for any of these mechanisms is currently lacking. By design, back belts reduce range of motion because the splinting and stiffening action of belts occurs about the lateral flexion and axial rotation axes, while stiffening about the flexion/extension axes appears to be less. van Poppel et al.³¹ published a paper on the mechanisms of action of lumbar supports (eg, back belts) in which they concluded that there is evidence that lumbar supports reduce trunk motion for flexion/extension and lateral flexion. However, these same investigators did not find evidence in the literature that lumbar supports influence back muscle EMG or intra-abdominal pressure. But, Cholewicki et al.⁶ demonstrated that both wearing an abdominal belt and raising IAP act independently or in combination to increase the stability of the lumbar spine. They also hypothesized that spinal stability due to increased IAP is likely achieved from the associated increase in muscle coactivation necessary to generate the IAP.⁶ In contrast, the spinal stabilizing effect of the belt by itself seems to be a passive mechanism.⁶

Several of the above proposed beneficial mechanisms of back belts can be related to posture (eg, range of motion, fatigue, spinal loading). Our laboratory has been investigating the role of seated and upright postures on the performance of goal-directed reaching tasks. The examination of reach postures and specifically the *transitions* between reach postures (a function of reach distance and task constraints) offers a method for providing clear distinctions between behavioral patterns. Recent work by Smart and Smith³² suggests that the dynamical nature of posture may be investigated by looking at postural instability, preferred modes of action, and movement transitions. Furthermore, they suggest that in lieu of being able to study the nervous system directly (in relation to energy expenditure and regulation), a behavioral analysis that emphasizes the study of global system dynamics is an attractive measure to investigate the system indirectly. Dynamical systems typically operate in a manner tending to minimize the energy necessary to achieve a given goal,³³ along with facilitating movement stability³⁴ through appropriate coordination of body segments.³⁵ While performing goal-directed activities, people change from one coordination pattern to another. In the case of reaching, we have examined the transitions from seated to standing reaches. In some situations, these transitions have been suggested as energy-saving mechanisms.³⁶ Observation of a wide range of motor activities (unconstrained by outside agents) reveals that individuals adopt a preferred action mode, which is sometimes referred to as *self-optimizing*.³⁷ This suggests preferred modes are self-selected and possibly optimal with respect to time, movement economy, or efficiency.³⁸

Posture has also been used to describe what is known as the margin of safety. Postures (joints) at the extremes of range of motion are at their greatest mechanical and physiological disadvantage.³⁹ Thus, a greater margin of safety means keeping people from potentially hazardous extreme ranges of motion.⁴⁰ Postural modes (coordination patterns) that minimize end ranges of motion therefore may be important in promoting an appropriate margin of safety.⁴⁰ Since the nature of the system's coordination dynamics is revealed around transitions (spontaneous changes in coordination pattern under the influence of some parameter, eg, reach distance),⁴¹ the factors that influence the onset and extent of such transitions are essential to postural stability and correspondingly to margin of safety. Methodologically, the observable behaviors can be differentiated from each other as stable patterns (attractors) before and after transition. Manipulation of the control parameters (eg, distance, velocity, etc.) of a movement thereby effects changes in the coordination pattern that we will refer to as a given *action mode*. Action modes (eg, standing reach) require a certain *postural configuration* (eg, upright stance with trunk and shoulder flexion) to complete the task. It is precisely the transition between action modes that we have investigated in this study.

The purpose of this study was to examine the effect of an external constraint (back belt) on reaching postures under different task conditions in a controlled test environment. The difference in this study is that traditional lifting methodologies were not used; rather, this investigation was based on a well-established set of procedures involving the investigation of postural changes during reaching.^{38,42} Why measure postural changes with or without use of a back belt and under different task conditions? From an action perspective, a back belt introduces a movement constraint (control parameter) on reaching actions. Additionally, task constraints also modify the control parameters. In this study, we used 2 tasks, one that demanded fine motor control and precise vision (reaching for and skewing a bead with a needle) and one that placed less stringent demands on motor control and vision (reaching for and picking up a Lego block [Lego Group, Earthstone, Calif]). For example, if an individual were to reach for and pick up a Lego block at a given distance in front of them, they would likely perform this gross motor activity with more velocity and variability than would be necessary in skewering a bead with a needle at the same reach distance. This is because the 2 tasks differ in both the visual demands and the amount of fine motor control and, hence, stability required to achieve their goal. As such, a back belt in the presence of different task constraints may influence the transitions between postures, coordination modes, and thus margin of safety.

The basic goal of the studies in the above citations was the analysis and determination of factors influencing postural *transitions* during reaching tasks (eg, task, distance of objects). To take a simple example, to reach an object placed relatively close to you (at a distance just longer than arm length), you can just bend your trunk and extend your arm to reach it. If the object is placed beyond this distance, you will need to move your buttocks off the chair to reach it. Thus, depending on the distance of the target, 2 different action modes (seated reach versus nonseated reach) and, hence, postural configurations are employed. One uses a trunk and upper extremity reach, while the second uses the trunk and both upper and lower extremities for reaching. However, a consistent finding from this set of studies in our laboratory is the transition point between configurations does *not* occur at the maximum distance set by the subject's anthropometry (eg, arm length) but at a closer distance. This transition point can be manipulated by changes in both task⁴² and starting postures.³⁸ In addition, our laboratory has also found evidence of *mode suppression* (the reduction in frequency of a particular mode of action) across different tasks.⁴² We have argued that the particular location of the transition point may reflect a user-generated margin of safety, protecting against overloading at the extremes of ranges of motion.⁴⁰ The use of a back belt in this study provided us the means to investigate a further constraint on reaching postures in addition to both task and initial posture. We hypothesized that a back belt (external constraint) would

affect the transition between modes of reaching postures by restricting the available range of motion. Specifically, we thought that when participants wore the belt, they would restrict their reaches to avoid extreme ranges of motion.

In our attempt to examine this idea of a margin of safety, we focused very carefully on the different action modes employed by actors when reaching with a back belt. Prior studies without using a belt have found that the most frequently used reach mode is the arm plus trunk (ie, arm and torso) reach.^{38,42} In the present study, we examined 3 different reach actions when using a belt: the seated arm and torso reach (reaching forward without removing or lifting the buttocks from the seat pan), the partial-standing reach (reaching forward while slightly bending the knees and lifting buttocks from seat pan), and the full-standing reach in which the legs are straight. Thus, the role of the back belt was to determine the effect of restricting range of motion on reaching behavior. To be sure, participants invoke a self-imposed limit while reaching, and presumably the back belt would restrict this limit even further.

METHODS

Overview

Sixteen young adults participated in 3 sessions of approximately 30 to 45 minutes each over a period of 2 weeks. In each session, subjects were instructed to carry out a series of reaching actions using 2 experimental tasks: reaching for and picking up a Lego block or reaching for and skewering a bead with a needle. The first session did not involve using the back belt. During the first session, we acquired necessary anthropometric data and found the locations of the preferred critical boundary for each subject. The second and third sessions required each participant to use the back belt on half of the trials. Between the second and third sessions, 8 of the 16 participants took the back belt home with them to use for 2 to 3 hours per day for 1 week. The dependent variables across the sessions included the type of reach mode employed and the reach distance at which a postural transition occurred.

Participants

Sixteen undergraduate students (8 male students, 8 female students) ranging in age from 18 to 22 years received monetary compensation for their participation in this experiment. The participants were screened and they signed informed consent documents indicating that a health practitioner had not treated them within the past 2 years for either a musculoskeletal disorder or high blood pressure. Each participant was tested individually. All participants were right-handed. We derived the number of participants required for this experiment from the following: (1) the effect sizes obtained in previous experiments^{38,42}; (2) consideration of the large number of trials

Table 1. Normalized distances—highest type 1 reach

Condition	Task	Mean	SD
Belt*	Bead	0.908	0.056
Belt†	Block	0.937	0.051
No belt†	Bead	0.921	0.056
No belt†	Block	0.935	0.039

All values represent normalized reach distances for the highest seated (Type 1) reach and are expressed as a proportion of the absolute critical boundary.

*.† denote statistically different conditions.

each participant was to complete during the course of the investigation; and (3) the additional power obtained from a predominantly within-subjects design.

Apparatus

The back belt (Back-A-Line, San Francisco, Calif) used in this study provided a stiff form-fitted surface in the lumbar region of the spine. The pad itself was 8 in tall, supporting the lumbosacral region. A single Velcro (Velcro USA, Manchester, NH) strap secured the belt in position. The belt came in 6 waist sizes, XS (23-28 in), S (27-32 in), M (31-36 in), L (35-40 in), XL (39-44 in), and XXL (43-48 in).

Participants sat on a Roc-N-Soc “drum throne” (Roc-N-Soc, Waynesville, NC). This chair is a stool with a padded “saddle” style seat, a small backrest, a 5-point support base, a turn wheel for backrest height adjustment, and a lever for seat pan height adjustment (adjustments ranged from 44 cm to 61 cm). The work surface was a motorized workstation, whose surface height was adjustable between 74 cm and 117 cm from the floor. The work surface was covered with black fabric.

A 50 × 118-cm black velvet covered board was placed on the work surface and was held in place by a large C-Clamp. The targets in the 2 experimental conditions were a 3 × 1.9-cm-high Lego block and a 4 × 2-mm-high black bead with a 2-mm diameter. The bead and the background were deliberately made the same color (to make the task more difficult to perform). Still, all participants were able to detect the bead and complete the skewering task without fail. Each session was videotaped.

Experimental Tasks

Two experimental tasks were used. In the block pick up task, participants were instructed to pick up the Lego block using the thumb and forefinger of the right hand. For the bead task, participants had to skewer the 2-mm bead using a sewing needle. The Lego block and the bead were placed at different distances (see Procedure: Session Organization and Structure for more information) from the participant, but these distances were always in the plane of the out-

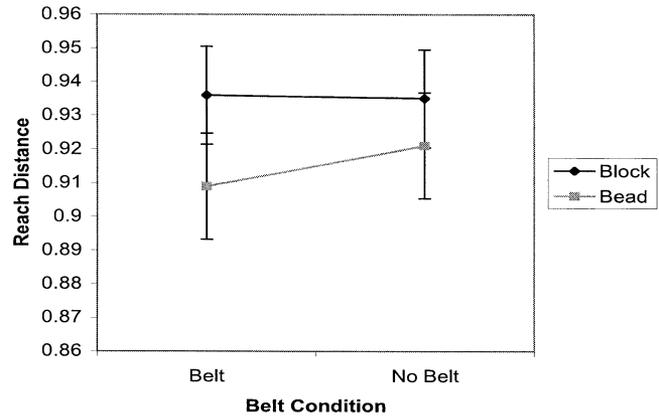


Fig 1. Normalized reach distance by task and condition for the Highest Seated (Type 1) reach.

stretched right arm. Participants were instructed to reach for these objects in any manner they chose comfortable. As soon as each reach was completed, participants were to resume a sitting posture, keeping their backs straight up against the back of the chair and feet flat on the floor until initiating the next reach. Between reaches, participants closed their eyes, during which time the target object was placed at the next location.

Procedure: Session Organization and Structure

Setup and calibration. Each session began by replicating the calibration procedures established by Gardner et al⁴² The goal of these procedures was to ensure that reach distances were normalized as a function of each subject’s maximum seated reach. Anthropometric measurements were taken of each participant to ensure that the workstation and stool were adjusted to fit them comfortably. These measurements consisted of the seated popliteal height (sole of the shoe to the underside of the thigh), seated shoulder height (the distance from the floor to the acromion), arm length (acromion to thumb tip), lower arm (crease of elbow to thumb tip), stature (floor to the top of head), and standing eye height (floor to eye). All measurements were taken with subjects either sitting on the edge of a table or standing against a wall.

The stool height was set to 105% of each of the participant’s popliteal height to ensure that the seat was a comparable height for each participant. Work surface height was set to the stool height plus one half of the participant’s seated acromion height (vertical distance from acromion to seat pan). The center of the seat post was positioned at a point on the floor 69% of the participant’s arm length from the edge of the work surface. This positioned the stool so that participants’ wrists were close to the edge of the work surface when the arms were fully extended from an upright position.

Table 2. Normalized distances—lowest type 3 reach

Condition	Task	Mean	SD
Belt*	Bead	1.008	0.065
Belt*	Block	1.124	0.048
No belt†	Bead	1.031	0.066
No belt†	Block	1.135	0.054

All values represent normalized reach distances for the lowest standing (Type 3) reach and are expressed as a proportion of the absolute critical boundary.

*† denote statistically different conditions.

Normalized reach distances were obtained by first asking each participant to extend their arm and place a block as far away from their bodies as comfortably possible while maintaining a seated position without sliding forward. Once this point was determined, the distance of the block was increased in 2-cm increments. The maximum reach capability or absolute critical boundary (ACB) for each participant was the point at which they could no longer reach the block without standing or sliding forward. Thirteen normalized reaching distances were calculated from 60% to 120% of the absolute critical boundary in 5% increments.

After determining normalized target placement distances relative to the ACB, participants were positioned at the workstation and instructed to either pick up the block or skewer the small black bead with a needle. In both conditions, each participant reached using their right arm. Targets were located in the plane of the right arm.

Session 1. At the start of the first session, participants were randomly assigned to 2 groups. Group 1 (8 participants) performed the block-reaching task first followed by the bead task. Group 2 (8 participants) performed the 2 tasks in the reverse order. For a given task (block or bead), each participant completed 2 reaches at each of 13 distances for a total of 52 trials per reach task condition. A random sequence of reach distances was used within each reach condition.

Session 2. The second session took place within 2 days of the first session. At the start of the second session, participants in Group 1 (block then bead) were further divided at random into 2 subgroups (4 participants per subgroup). The first subgroup wore a belt while performing the block and bead tasks and then performed the same pair of tasks again without wearing the belt. The second subgroup started performing the block and bead tasks without the belt and then switched to wearing the belt. Participants in Group 2 (bead then block) were randomly assigned into 2 subgroups (4 participants per subgroup). The first subgroup wore the belt initially for both pairs of tasks and then performed the same tasks without the belt. The second subgroup began the reach tasks without wearing the belt and then switched to the belt condition.

All participants were fitted with an appropriate back belt for their waist size. Participants wore the same belt throughout the experiment. Although minimal instruction was given

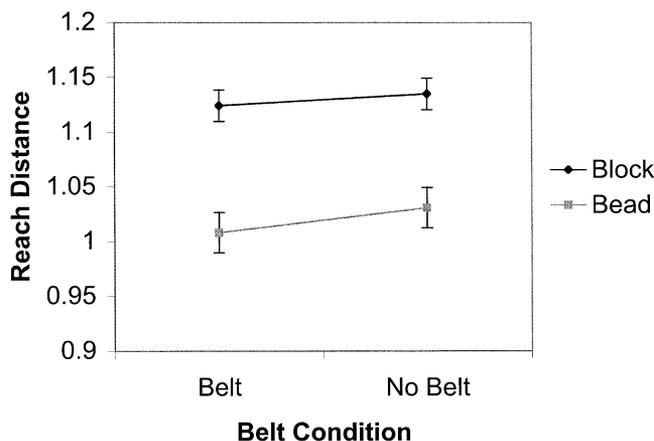


Fig 2. Normalized reach distance by task and condition for the Lowest Standing (Type 3) reach.

on the proper use of these belts, experimenters informed participants that the pad of the belt should be directed at the lumbar curve and the Velcro strap should be fastened so that the belt fit “snuggly.” Participants were told to fasten the belt so that it was firm, yet comfortable.

At the conclusion of the second session, 4 of the 8 participants in each group were randomly assigned to one of 2 conditions: take home a back belt or not. Those who were selected to the take home condition were given their back belt and instructed to wear the belt for a period of 2 to 3 hours per day for 1 week prior to session 3. This group was also provided journals and asked to record each daily activity that they engaged in while wearing the back belt.

Session 3. The third and final session took place a week after session 2. Participants were given the same group and subgroup assignments as they had during the second session.

RESULTS

Coding of Videotapes

All reaches were videotaped. Two graduate students independently viewed each reach for the purpose of classifying each of the reaches into one of 3 modes (seated reach, partial stand, full stand). Where the coders differed in their classification, they discussed the reach until they achieved agreement. The reach modes (postural configurations) were differentiated by the following criteria: a type 1 reach corresponded to a seated reach in which the buttocks of the participant were in contact with the chair at all times, irrespective of trunk or upper extremity angulation; a type 2 reach corresponded to a partially standing or “squat” reach in which the buttocks did not remain in contact with the chair and the knees never fully extended; a type 3 reach corresponded to a “standing” reach in which the buttocks did not remain in contact with the chair and the knees fully extended at least momentarily.

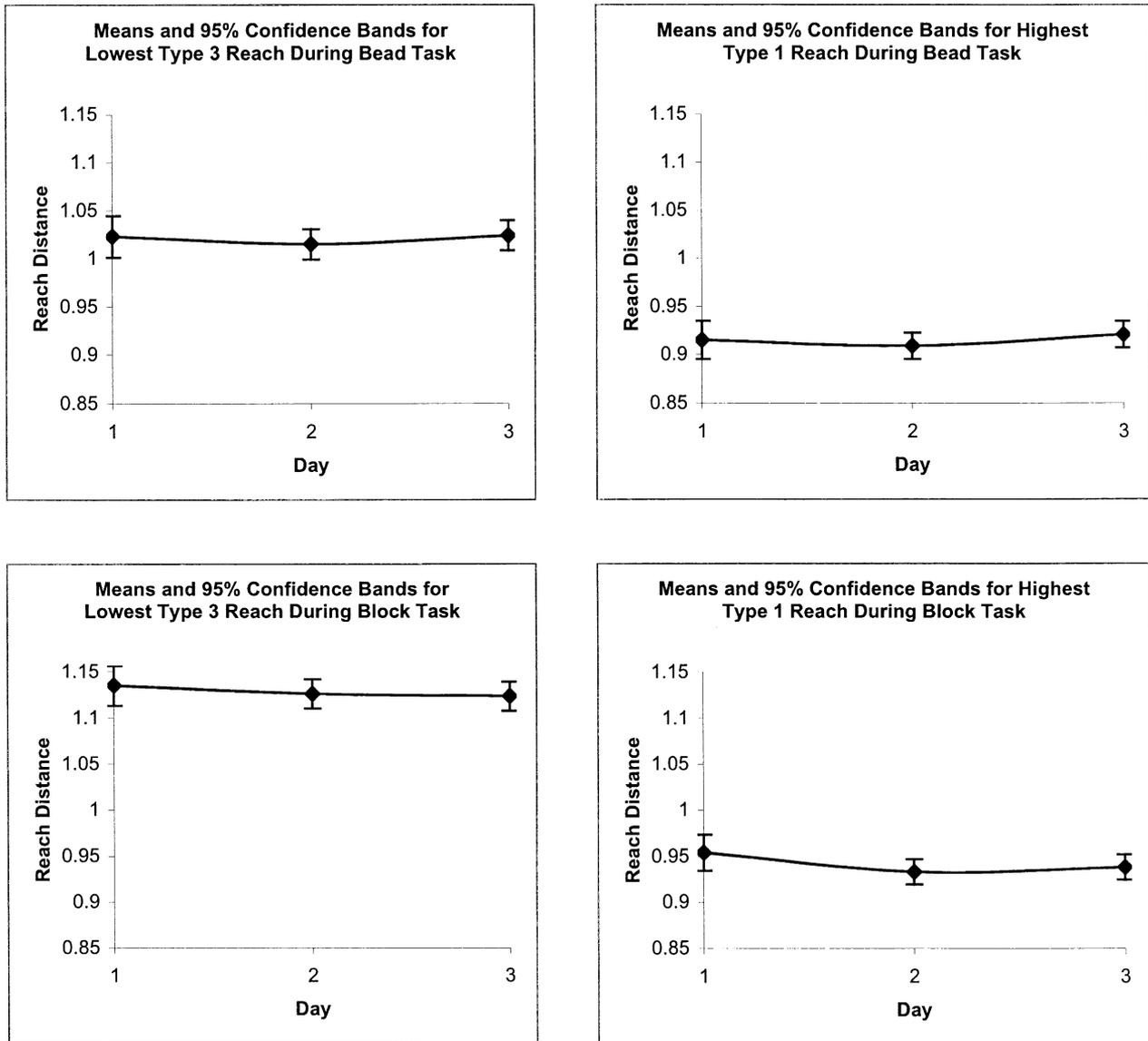


Fig 3. Normalized reach distances across days (sessions) for task, condition, and type of reach.

The data for 3 subjects had to be eliminated because of an experimenter error in measuring the prescribed reach distance. All 3 were males subjects in the condition that did not take home the back belt. Thus, 13 subjects remained in the final analysis: 8 took home the back belt and 5 did not.

Analysis of Variance

A 4-factor mixed design was used in this experiment. The between-subject variable was the belt take home condition. The within-subject variables were Day (day 2, day 3), Condition (belt, no-belt), and Task (bead, block). Condition and Task were completely counterbalanced. The dependent measure was the reach mode used.

The resulting data matrix included 208 (13 subjects \times 2 days \times 2 tasks \times 2 reaches per task \times 2 belt or no-belt condition) observations (transition ratings) obtained on a total of 13 subjects across 2 days. Data from Day 1 (baseline) were not entered into the analysis of variance (ANOVA). Of these 13 subjects, 8 took the belt home during the period between days 2 and 3, while 5 did not have a belt to take home during this period.

Two separate analyses of variance programs were run using the SAS General Linear Model Procedure (SAS Institute Inc, Cary, NC).⁴³ The first was a completely within-subjects $2 \times 2 \times 2$ design, in which the factors were Day (2 or 3), Condition (belt or no-belt), and Task (block or bead). The second was a mixed $2 \times 2 \times 2 \times 2$ design, for which the within-subjects factors were Day (2 or 3),

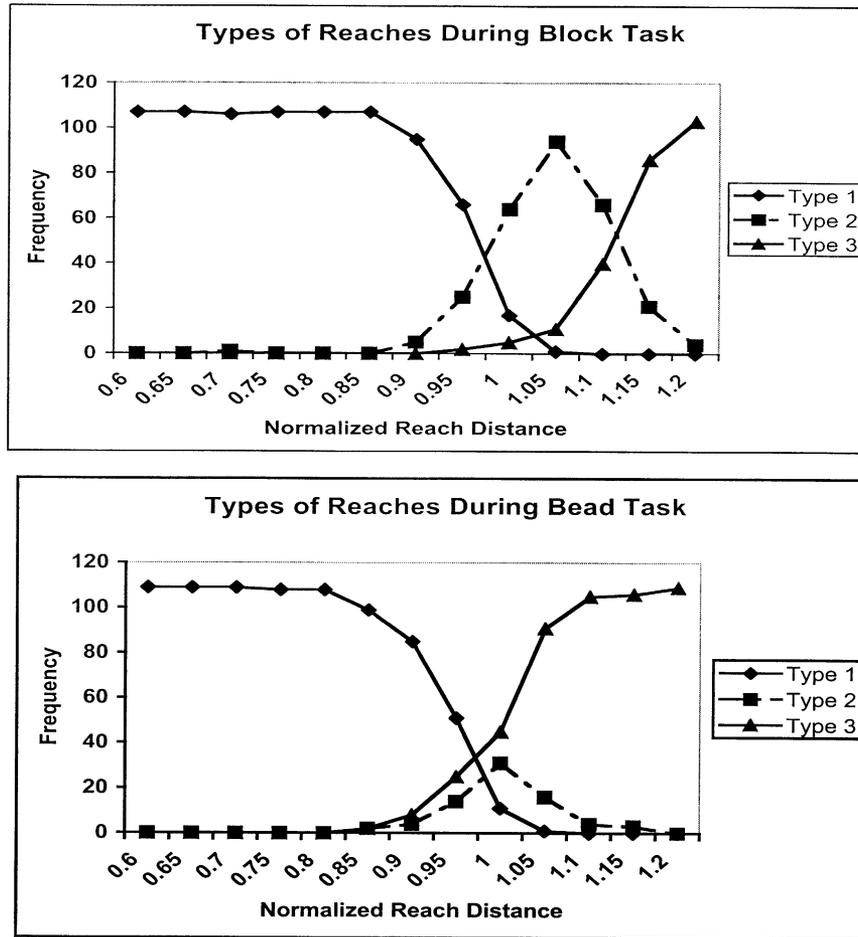


Fig 4. Frequency of Type 1, 2, and 3 reaches combined across days and condition for both tasks.

Condition (belt or no-belt), and Task (block or bead), and the between-subject factor was Belt Worn at Home (yes or no).

Primary–Analysis–Transition from Seated Posture

The primary focus of this study was on the location of the transition between seated and standing (either partial-standing or full-standing) reaches. This is defined as the farthest distance (Highest Type 1) at which subjects reached for the object (bead or block) while using a seated reach only. The repeated measures analysis of variance found a significant interaction between Condition (belt, no-belt) and Task (bead, block), $F_{1,13} = 6.59, P = .0234$. This means that on average, participants wearing the belt changed from a seated reach to a nonseated reach at closer distances when performing the bead task. There was also a significant main effect of Task, $F_{1,13} = 8.71, P = .0113$, such that on average, bead tasks resulted in transitions from seated to nonseated reaches at closer distances than block tasks.

Table 1 contains mean values and SDs for normalized reach distances for the highest seated (Type 1) reach, summed over the between-subject factor. Mean values and 95% confidence bands are plotted in Figure 1.

Figure 1 shows that when wearing the back belt, subjects skewering the bead changed from a seated arm and torso reach at significantly shorter distances than while not wearing the belt. However, the difference between bead and block tasks did not apparently affect reach transitions when subjects did not wear the belt.

Analysis–Transition to Full Standing

A secondary focus of attention was on the final transition to full standing. This is defined as the lowest distance (Lowest Type 3) at which subjects reached for the object (bead or block) while standing with legs straight. Note that since subjects could make this transition either from a Type 1 or Type 2 reach, this analysis is less clear-cut than in the previous case. The repeated measures analysis of variance indicated significant main effects of Condition (belt or no-belt), $F_{1,13} = 4.72, P = .0489$, and Task (bead or block), $F_{1,13} = 93.31, P = .0001$, at the point that subjects performed a fully standing reach. However, unlike the previous analysis, the Task by Condition interaction was not significant. Thus, subjects skewering the bead and grasping the block changed to full standing at significantly closer distances

Table 3. Type 3-type 1 differences in normalized reach distances

		Mean	SEM
Condition	Belt	0.114	0.014
	No belt	0.155	0.0150
Task	Bead	0.104	0.010
	Block	0.194	0.019

All values represent differences between normalized reach distances for the highest Type 1 reach and the lowest Type 3 reach expressed as a proportion of the absolute critical boundary.

while wearing the belt than while not wearing the belt. In addition, the bead task was completed at closer distances than the block task irrespective of wearing a belt or not.

Table 2 contains mean values and SDs for normalized reach distances for the lowest standing (Type 3) reach. Mean values and 95% confidence bands are plotted in Figure 2. Note that in this case as before, a reach distance of 1.0 is the furthest possible seated reach.

Effects of Experience with Belt

We did not find evidence that experience using the belt over the course of the experiment affected the locations of reach transitions. The results of the completely within-subjects ANOVA for the initial transition from sitting (Highest Type 1) indicated that while the main effect of Day was significant, $F_{1,12} = 6.33$, $P = .013$, Day, as a factor, did not interact with either Condition or Task. Mean normalized reach distance was 0.92 on Day 2 but increased to 0.93 on Day 3. The comparable analysis for the last transition (Lowest Type 3) showed a significant Day by Task interaction, $F_{1,12} = 5.76$, $P = .018$. The interaction pattern indicated that on Day 2, the difference in mean normalized reach distance between bead (1.02) and block (1.36) was larger than the comparable distances (1.02 versus 1.12) on Day 3. However, Day did not interact with the main effect of Condition (belt versus no-belt) or with any Condition interaction.

Recall that subjects were given an initial session (Day 1) prior to being introduced to the belt. While Day 1 data were not entered into the analyses of variance, we can assess the overall effect of experience by plotting mean normalized reach distances and 95% CIs for Type 1 and Type 3 transitions for bead and block tasks across all 3 days of the study. These plots appear in Figure 3 and do not appear to reveal a consistent trend across days. While these data are for no-belt trials only, the analysis of variance failed to find that belt condition was statistically related to experience across days.

The experience issue was directly addressed by the mixed analysis of variance, in which, during the week between Day 2 and Day 3 sessions, one group of subjects was asked to wear the belts at home for 2 to 3 hours per day, while a second group was not given the belts. There were 8 subjects who

took the belts home and 5 subjects who did not. Examination of the logs provided by the subjects and interviews with them indicated that they appeared to conscientiously follow the instructions. However, the analysis of variance failed to indicate that this between-group variable was significant in itself, nor did it interact with any other variable. Hence, we could not say that experience with the belt during the week at home had any effect on Day 3 reaches.

Analysis of Partial-Standing Type 2 Reaches—Mode Suppression

As the object to be grasped is placed beyond the subjects' preferred critical boundary (PCB) (the point at which actors prefer to transition from one action mode to another) for seated reaching, each individual has, in effect, a choice among 2 types of reach. Either an intermediate, partial-standing reach (Type 2) can be used or the subject can go immediately to a full-standing reach (Type 3). The original work of Gardner et al⁴² observed evidence of mode suppression, that is, the reduction in frequency of partial-standing reaches in the bead task as compared with the block task.

Figure 4 indicates how the frequencies of the 3 reach configurations change as reach distance increases. As reported by Gardner et al,⁴² these data, which are combined across day and belt condition, clearly show the existence of mode suppression. Partial-standing reaches are much less frequent for the bead condition (5.5% of the total) than for the block condition (20.8%).

Did wearing a belt affect the frequency of the partial-standing mode? Because of the large variability in frequency of Type 2 responses, using this response as a dependent variable in an analysis of variance was inappropriate. An alternative method of examining the question involved definition of a new variable. For each reach action, the difference in reach distance between the furthest seated reach (Type 1) and the first subsequent fully standing reach (Type 3) was calculated. Note that reach distances varied in increments of 0.05; therefore, the lowest possible difference was 0.05. This would represent the situation in which the subject used a standing posture immediately following a seated posture. Thus, a larger difference score indicates a larger number of Type 2 reaches interposed between sitting and standing.

As expected from examination of Figure 4, difference scores were significantly higher in the block task compared with the bead task ($F_{1,12} = 253.52$, $P < .001$). However, difference scores were also significantly higher in the no-belt condition than in the belt condition ($F_{1,12} = 3.92$, $P = .05$). The Condition by Task interaction was not significant ($F_{1,12} = 0.07$, $P > .5$). Mean values of normalized reach distances and SEMs are found in Table 3. These findings indicate that, while the partial-standing reach was used less often during the bead task, wearing the belt also made it less likely that the subject would adopt a partial stand posture in either task.

DISCUSSION

Posture is not maintained for its own sake but rather facilitates suprapostural behaviors such as reading, reaching, or looking.³² Humans are dynamical systems that interact within their environment to achieve goals. To realize these goals entails stable postures and movements. The lack of stability compromises efficient interactions (perception-action) with the world. Postural control then is necessary to all actions and requires coordination and stabilization of all bodily members. Reaching specifically can be considered a suprapostural activity requiring stability for its successful performance.

From this perspective, it would seem that for industrial back belts to be effective, they should have some impact on postural stability. Here, we have reported on basic research of postural changes related to wearing a Back-A-Line (BAL) back belt. The BAL belt is different from previous belts predominantly in its design. It is a stiff, form-fitting belt providing support for the lumbar curve and has 1 large Velcro strap. This belt is not elastic and does not have metal stays or harness support like common belts. The presumed effect of this design is to provide increased spinal stability.

The results from the primary analysis of the transition from seated arm and torso reach indicate that when subjects wore the belt while reaching, the transition points were *closer* to their bodies than while not wearing the belt. This occurred for only the bead task, which required more postural stability. Hence, the belt seems to act to preserve a greater margin of safety, keeping the user from extreme ranges of motion. Mark et al³⁸ state:

“Making the transition from one action mode of goal-directed action to another at the preferred critical boundary provides actors with a *margin of safety*, which might be thought of as the distance between the absolute and preferred critical boundaries. This minimizes actors’ exposures to potentially dangerous situations in which they are unable to complete an action because it is not afforded by the existing layout. The magnitude of the margin of safety varies with the situation. When an action has to be completed quickly, actors might allow a greater margin of safety compared with situations when their intention is to perform carefully.”

Posture of the lumbar spine is an important issue in injury prevention for numerous reasons but particularly because compressive strength of the lumbar spine decreases when the end range of flexion is approached.⁴⁴ If belts restrict the end range of motion, one might expect the risk of injury to decrease. It is interesting, however, that this effect only seems to happen when the task (picking up a small bead with a needle) requires a posture that is to be maintained for more than a second or two. There was no difference in transition point when subjects were asked to perform a simpler task (picking up a block).

What is it that makes the bead task more difficult? There are several important differences: the targets (needle and bead diameter) for the bead task are much smaller than for

the block task and postural requirements for the hand are more precise; a precision grip rather a power grip is needed for the bead task. Inherent in these task elements is a differential requirement for postural *stability*. Gardner et al⁴² (Experiment 3) provide evidence that postural stability was the key difference between accomplishing bead versus block tasks. The greater degree of fine motor control entailed in skewering the bead requires stable supporting links (arm, trunk, legs). The difference in outcomes between tasks can, if verified in subsequent research, lend credence to the argument that the potential protective aspect of the belt is manifest when the task requires postural stability. Moreover, following the suggestion of McGill,³ we might speculate that this protective effect is manifest through proprioceptive feedback signaling the approach of the limits of ranges of motion.

The general argument that the bead task requires a greater degree of postural stability can be supported by the data on mode suppression. A partial stand/squatting posture is much less likely to be used in the bead task than in the block task. Presumably, this is due to the inherent instability of the partial stand. This makes sense biomechanically; more effort is required to hold trunk and arms stable during the squat posture.

It is interesting that while examining the final transition to full-standing reach, the difference between tasks disappears. Here the apparent protective effect of the belt works for both bead and block tasks. What are the conditions under which this final transition occurs? The target is now placed beyond the seated reach capability of the subject, and she/he must move out of the chair. We can argue that this type of transition is inherently less stable and that it makes sense that, for both tasks, the subject will move to the more stable standing posture sooner while wearing the belt. Presumably this would result from the postulated proprioceptive feedback mentioned earlier.

Furthermore, this effect does not appear to require a great deal of experience with the belt. The lack of difference in the belt effects between days 2 and 3 and the lack of effect of extra experience at home would be consistent with the argument which holds proprioceptive feedback from the belt is detected and utilized by subjects quite early in the course of experiment. These arguments await further confirmation in additional laboratory tests, since our current design was not optimally suited to examine the effect of experience wearing the belt.

It should be noted that the effect of the belt on the preferred critical boundary was small but significant in this study. The practical relevance of such a finding must be tempered with the knowledge that the sample in this study consisted of young and presumably healthy adults. The obvious question then is what would the results be for adult workers with work-related injuries, musculoskeletal dysfunction, and/or symptoms? From a chiropractic perspective, how might vertebral subluxations impact the location

of transition points and action modes? Although we have not performed such studies, it may be hypothesized that musculoskeletal disorders and/or vertebral subluxations would alter the preferred critical boundary (eg, by means of physical limitation, inappropriate modes of coordination, etc.) and that an extrinsic constraint on motion (eg, back belt) might further change the location of the PCB.

Caution must be used when interpreting the results of this study, as only select postures were used and a detailed kinematic investigation was not performed. For example, Sparto et al.¹⁹ demonstrated that the use of a belt restricted sagittal trunk range of motion and velocity, while the hip motion and velocity increased. In addition, they stated that although one of the risk factors for acquisition of low back pain may be reduced while wearing the belt, the results raise questions about the risk of injury to other joints.¹⁹

Finally, it is known that numerous factors contribute to occupational low back disorder⁴⁵ and musculoskeletal injury causation.³⁹ One of these factors is posture in terms of tissue loading responses, frequency and repetition of motion, duration, etc. However, it would be naïve and shortsighted to think that any single intervention or short-term solution exists to overcoming low back and musculoskeletal disorders, especially pain. This is well characterized by the work of Feuerstein et al.,^{46,47} who have shown the multivariate nature of low back disability, including such factors as age, occupational stress, general worries, and social support.

CONCLUSION

The BAL belt consistently modified reaching postures by limiting extreme ranges of motion during a task that required enhanced stability. It is hypothesized that avoiding extreme ranges of motion over time may prevent certain injurious situations. To investigate the potential health benefits of the BAL belt in industrial or other settings will require additional study (more subjects, natural work conditions, comparison against more traditional belts, etc). It would also be attractive to chart the course of back pain incidents in subjects wearing or not wearing the belt while engaged in extended tasks that require long reaches and a transition from a sitting to standing position. Future research is needed to quantify the degree to which an individual operates within a given mode of behavior (eg, seated reach), the ranges of movement (operating within preferred regions or near extremes) within that behavior, and the transitions that occur to allow other behaviors (eg, sit-stand). These factors must then be related to health and safety outcomes. The speculation as to the clinical usefulness of this belt to an individual is beyond the scope of our article. As with any clinical issue, the decision to prescribe belts should be at the discretion of the chiropractor. Our laboratory is interested in continuing this line of investigation, as well as extending this type of

analysis to the effects of chiropractic care. Finally, it must also be emphasized that even if the demonstrated effectiveness of the BAL belt is supported in further research, such belts are an adjunct to, not a replacement for, good ergonomic design and chiropractic care.

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