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Postural Evaluation of a New Back Belt Design

Marvin Dainoff, Leonard Mark, Shawn Oates, and Dean Smith

Abstract

A newly designed back belt (Back A Line) is now available. The belt is not elastic, but provides a stiff form-fitted surface in the lumbar region of the spine. It is argued that this design will actually stimulate abdominal muscles by providing resistance.

The potential effectiveness of the new back belt was evaluated in a controlled laboratory test. This test is based on a well established set of procedures developed in our laboratory involving the investigation of postural changes during reaching.

The basic goal of these studies was the analysis and determination of postural *transitions* during reaching tasks. To take the simplest example, for me to reach an object placed relatively close to me (at a distance less than my arm length), I can just extend my arm. If the object is placed at a distance longer than my arm length, I will need to bend my trunk to reach it. Thus, depending on the distance of target, two different *postural configurations* are employed. One uses an arm-only reach; the second an arm-plus-trunk reach. 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 (e.g., arm length) but at an closer distance. This transition point can be manipulated by changes in both task and starting postures. 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.

Preliminary results indicate that when subjects wore the belt while reaching, they tended to have transition points *closer* to their bodies, than while not reaching. Hence, the belt seems to act to preserve a greater margin of safety--keeping the user from extreme ranges of motion. It is interesting, however, that this effect only seems to happen when the task requires a great deal of stability (picking up a small bead with a needle.) There was no difference in transition point when subjects were asked to perform a simpler task (picking up a block.) This difference in outcomes between tasks can, if verified, lead credence to the argument that the potential protective aspect of the belt is manifest when the task requires postural stability.

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INTRODUCTION

The use of back belts to prevent musculoskeletal injuries has been controversial. The National Institute of Occupational Safety and Health (NIOSH, 1994) 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 during manual lifting.…backbelts **do not** mitigate the hazards to workers posted by repeated lifting, pushing, pulling, twisting and bending. .(pp.1-2):

Similar sentiments have been expressed by the Agency for Health Care Policy and Research (Bigos et al., 1994) who 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. (1999) cite several papers that indicate to date, it appears that abdominal belts are widely prescribed in both industry and rehabilitation without a convincing scientific justification of their benefits. So it appears then that the use of lumbar belts in industrial settings continues to be widely debated. The source of claims supporting the use of support belts to reduce injury have been both from an injury prevention/ and or rehabilitation perspective.

More recent reviews of the literature have not departed markedly from these conclusions (Rhys and Contreras, 1998; McGill, 1999.) McGill (1999; p. 1354) identifies the following proposed mechanisms for potentially beneficial effects of back belts.

(1). Reminder to lift properly
(2) Support shear loading on spine
(3) Compressive load reduced through increased 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

McGill indicates that strong evidence for any of these mechanisms is lacking. There is some evidence for the reduction of range of motion hypothesis, but not the plane of flexion.

A newly designed back belt (Back a Line) may provide an alternative approach. This belt is not elastic, but provides a stiff form-fitted surface in the lumbar region of the spine. It is argued that this design will actually stimulate abdominal muscles by providing resistance.

The purpose of this study was to examine the potential effectiveness of the new back belt design 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. (See: Dainoff, Mark and Gardner, 1999; Mark, Dainoff and Gardner, 1999; Mark, Dainoff, Gardner and Cicak, 1999; Mark, Nemeth, Gardner, Dainoff, Passche, Duffy, and Grandt, 1997; Gardner, Paasche, Edkins, Hirons, Mark, and Dainoff, 1997.)

The basic goal of the studies in the above citations was the analysis and determination of postural *transitions* during reaching tasks. To take the simplest example, to reach an object placed relatively close to you (at a distance less than arm length), you can just extend your arm. If the object is placed at a distance longer than an arm length, you will need to bend your trunk to reach it. Thus, depending on the distance of the target, two different *postural configurations* are employed. One uses an arm-only reach; the second an arm-plus-trunk reach. 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 (e.g., arm length) but at a closer distance. This transition point can be manipulated by changes in both task and starting postures. 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.

In our quest to examine this idea of a margin of safety, we focused very carefully on the different posture configurations employed by actors when reaching. Prior studies have found (Dainoff, Mark and Gardner, 1999; Mark, Dainoff and Gardner, 1999; Mark, Dainoff, Gardner and Cicak, 1999; Mark, Nemeth, Gardner, Dainoff, Passche, Duffy, and Grandt, 1997; Gardner, Paasche, Edkins, Hirons, Mark, and Dainoff, 1997.) that the most frequently used reach mode is the arm – plus – trunk (i.e. arm and torso) reach. In the present study, we expounded this theory and examined three specific arm and torso reach actions: the seated reach, (reaching forward without removing or lifting the buttocks from the seat pan), the partially standing reach, (reaching forward while slightly bending the knees and lifting buttocks from seat pan), and the fully standing reach.

METHOD

Participants

Thirteen undergraduate students ranging in age from18 to 22 received monetary compensation for their participation in this experiment. The participants were screened and signed informed consent documents indicating that they had not been treated by a physician within the past two years for either a musculoskeletal disorder or high blood pressure. Each participant was tested individually and all were right-handed.

Apparatus

Seating provided for participants was a Roc-N-Soc "drum throne" (Roc-N-Soc, Waynesville, NC). This seat is essentially a stool with a padded "motorcycle 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 44-61 cm.). The worksurface was a motorized workstation, with surface height adjustable between 74 –117 cm. from the floor.

A 50x118 cm. black velvet covered board was placed on the worksurface and was held stabled by a large c-clamp. The targets in the two experimental conditions were a 3 cm. square by 1.9 cm. high Lego block and a 2 mm diameter black bead.

Procedure

Session Organization and Structure

The study involved three daily sessions of approximately 30 to 45 minutes each, over a period of two weeks. At the onset of the first daily session, (i.e. the baseline measure), participants were randomly assigned to two groups: Group X wore no belt and performed task 1 (block) first, then task 2 (bead) using both random number sequence A and B. Group Y wore no belt and performed task 2 then task 1 using both random number sequence A and B. At the onset of the second daily session, participants were further randomly assigned into four groups consisting of: Group1 who wore a back belt first, then no belt and performed task 1 (block) and then task 2 (bead) using both random number sequence A and B. Group 2 who wore a back belt first, then no belt and performed task 2 (bead) and then task 1 (block) using both random number sequence A and B. Group 3 who wore no back belt first, then a back belt and performed task 1 (block) and then task 2 (bead) using both random number sequence A and B. Group 4 who wore no back belt first, then a back belt and performed task 2 (bead) and then task 1 (block) using both random number sequence A and B.

The study was organized as follows: On the first daily session subjects were instructed to carryout a series of reaching action using both experimental tasks, (block and bead), without wearing a back belt. During the second daily session, the reaching actions were repeated and participants were given a back belt to wear during half of their reaching s. At the conclusion of the second daily session half of the participants were randomly assigned to one of two conditions: take home a back belt or not. Those who were selected to the take home condition were given a back belt and instructed to wear the belt for a period of 2 to 3 hours per day for one week prior to daily session three. This group was also provided journals and asked to record each daily activity that they engaged in while wearing the back belt. After a one-week period, the third and final daily session began. Participants returned the belts and journals and repeated the same series of reaching action.

Setup and Calibration

At the onset of each test session 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 in order to ensure that the seat was a comparable height for each participant. Worksurface height was set to the stool height plus one half of the participant's seated acromion height. The center of the seatpost was positioned at a point on the floor 69 percent of the participant's arm length from the edge of the worksurface. This positioned the stool so that the participant's wrists were close to the edge of the worksurface when the arms were fully extended from an upright position.

To establish each participants Preferred Critical Boundary, (PCB - the point at which the relative comfort and efficiency of two action modes change), they were asked 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 achieved, we then established the maximum reach or what's referred to as the Absolute Critical Boundary, (ACB – the point at which an actor is no longer capable of using one mode, and must change to another to accomplish a set goal i.e. a reaching distance), for each participant. This was accomplished by increasing placement of a block forward by 2cm. from the point each participant indicated was their PCB until they could no longer reach the block without standing or sliding forward. Reaching distances were calculated from 60 – 120% of the maximum arm-and torso reach in 5% increments.

After determining the distances at which targets were placed, 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. All participants participated in all conditions and the conditions were counterbalanced across participants. Each participant completed two reaches at each of 13 distances total of 52 s per condition. These s were randomly ordered.

Experimental Design
A 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). Each combination of the experimental condition was administered to each subject in a randomized sequence. The dependent measures were the three reach modes: seated reach (Type 1), partially standing reach (Type 2), and the fully standing reach (Type 3).

RESULTS

Coding of Videotapes
A videotape record was used in this experiment to capture the reaching and postural transition points of each subject at every test session. The videotapes served two purposes: (a) to classify each of the reaches into one of three modes; and (b) to clarify any points of conflict between the two researchers viewing and recording the various reach modes. One scorer would watch a subject and code the appropriate reach and postural motions while the second watched on a video terminal and recorded the same reach and postural motions. At the conclusion of each trial session, the two researchers would view the videotapes and compare scores. Any potential conflicts in scoring were resolved by discussion at this time. The videotapes were viewed only by the researchers involved in this study and did not contain personal information about the subjects. The subjects were informed that they were being tape-recorded and were given the option not to participate in the experiment if they objected.

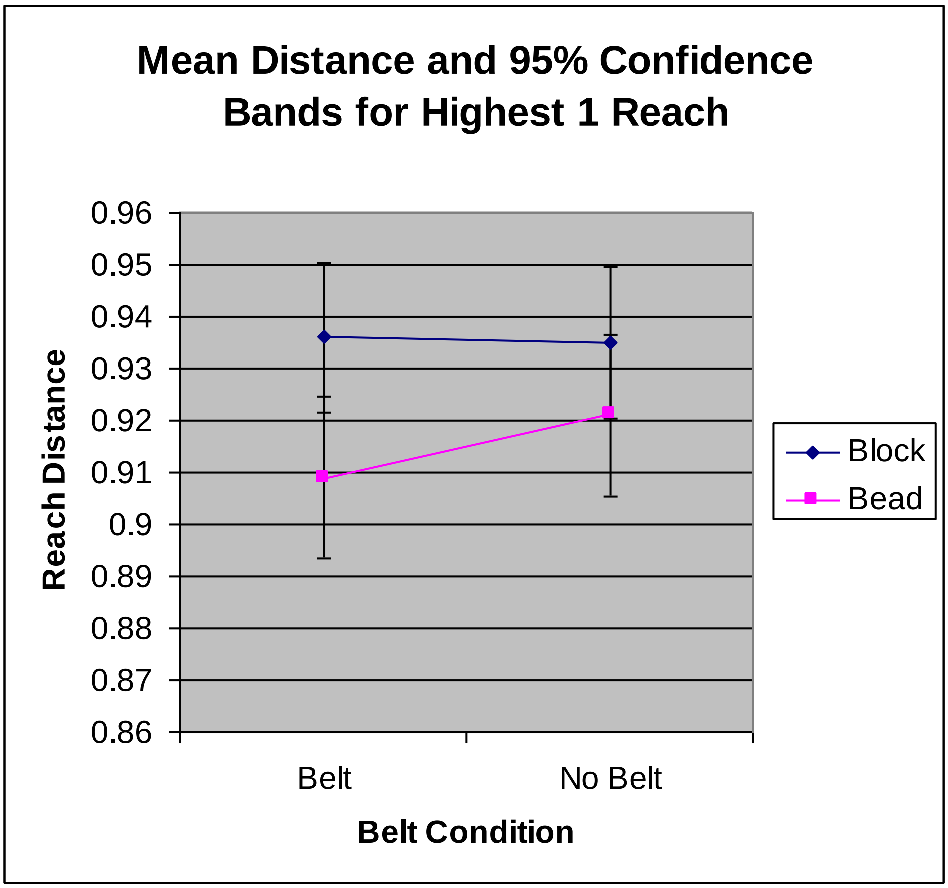
Analysis of Variance
The resulting data matrix included 201 observations (transition ratings) obtained on a total of 13 subjects across 2 days. These were all of the subjects who participated completely on all three days. (Data from Day 1 (baseline) were not entered into the analysis of variance.) Of 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, 1990). The first was a completely within-subjects 2 by 2 by 2 design, where the factors were Day (2 or 3), Condition (belt or no belt) and Task (block or bead). The second was a mixed 2 by 2 by 2 by 2 design, where the within-subjects factors were Day (2 or 3), 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 first transition point. This is defined as the highest distance (Highest Type 1) at which subjects reached for the object (bead or block) while using an arm and torso reach only. The repeated measures analysis of variance found a significant interaction between Condition (belt, no belt) and Task (bead, block), $F(1,13)=6.59$, $p=.0234$. . There was also a significant main effect of Task, $F(1,13)=8.71$, $p=.0113$.

Table 1 contains means and standard deviations for normalized reach distances for the highest type 1 reach. Means and 95% confidence bands are plotted in Figure 1. Reach distances are normalized by defining the Absolute Critical Boundary (the furthest reach possible using arm and torso) as a reach distance of 1.0. Thus, individual reach distances for each subject can be scaled as a proportion of that subject's Absolute Critical Boundary.

Figure 1. Normalized Reach Distance by Task and Condition—Highest 1



When wearing the back belt, subjects skewering the bead transitioned 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 while subjects did not wear the belt.

Table 1. Standardized 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

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. 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 case, the Task by Condition interaction was not significant.

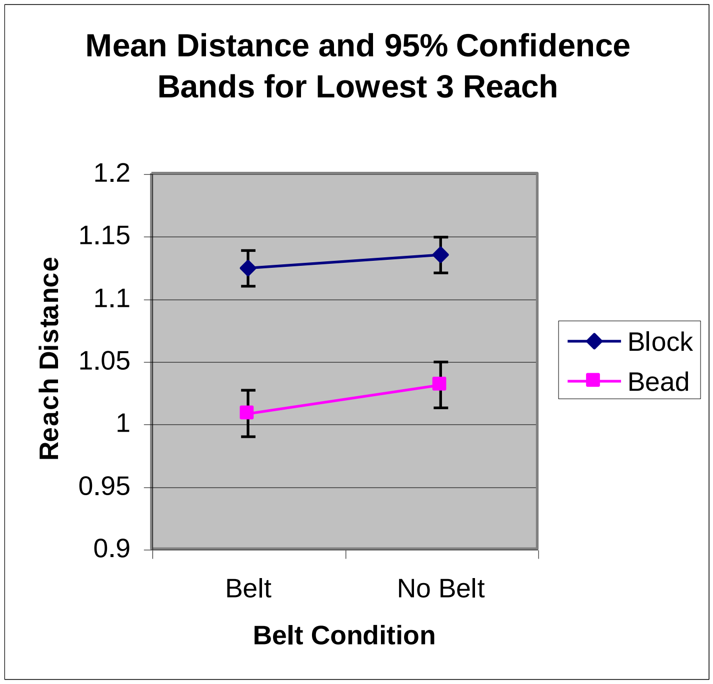
Table 2 contains means and standard deviations for normalized reach distances for the highest type 1 reach. Means and 95% confidence bands are plotted in Figure 2. A reach distance of 1.0 is the furthest reach possible using arm and torso.

Thus, subjects skewering the bead and grasping the block transitioned to full standing at significantly shorter distances while wearing the belt than while not wearing the belt.

Table 2. Standardized 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

Figure 2. Normalized Reach Distance by Task and Condition—Lowest 3

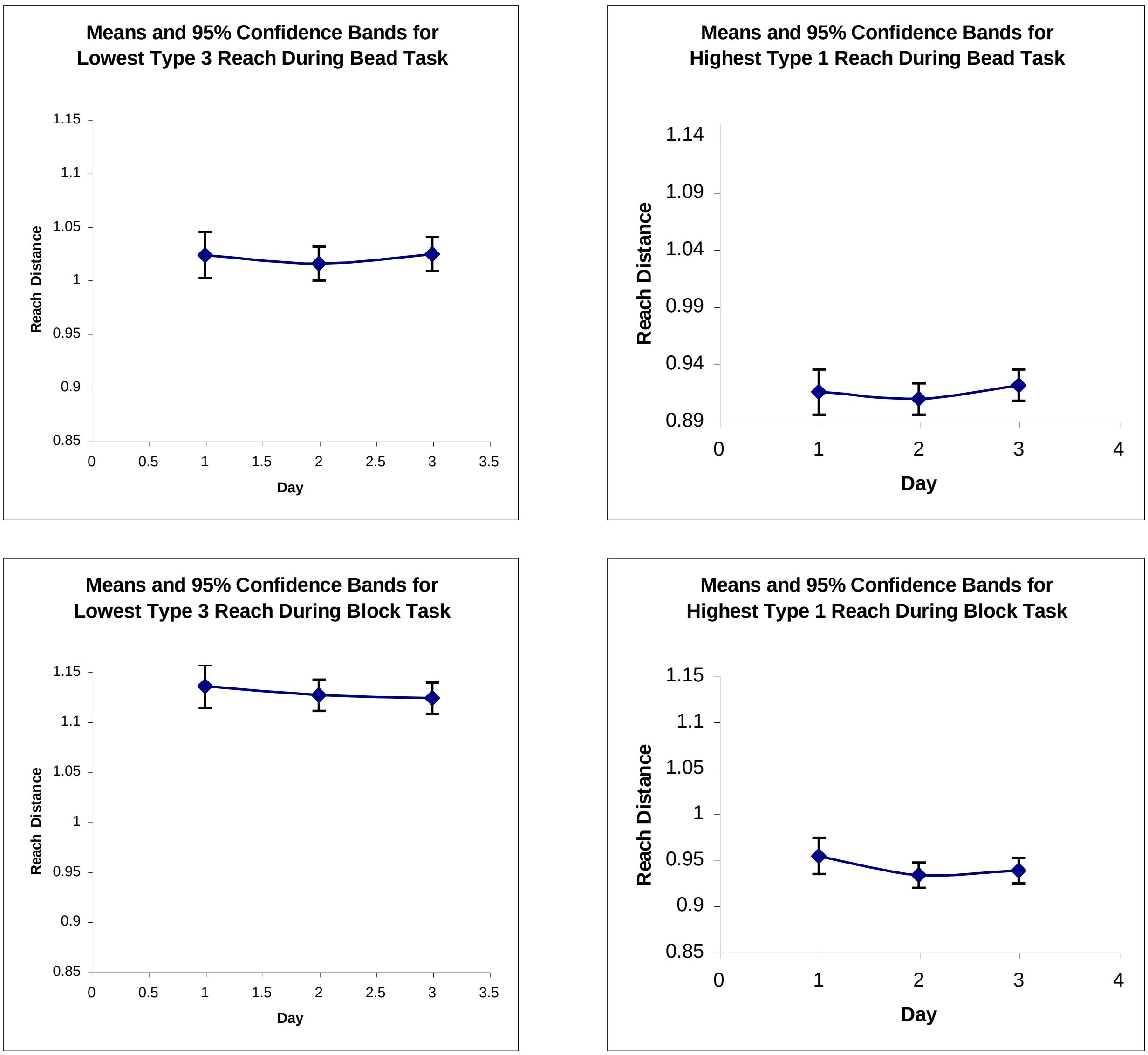


Effects of Experience with Belt.

We could find no evidence that experience gained using the belt over the course of the experiment had any differential effect on types of reach transitions. The results of the completely within subjects ANOVA for the initial transition (Highest 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 Condition or Task. Mean normalized reach distance was 0.92 on Day2, but increased to 0.93 on Day 3. The comparable analysis for the last transition (Lowest 3) showed a significant Day by Task interaction, $F(1,12)=5.76$, $p=0.018$. 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 vs. 1.12) on Day 3. However, Day did not interact with the main effect of Condition (belt vs. no belt) or with any Condition interaction.

Recall that subjects were given an initial session (Day 1) prior to be 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% confidence intervals for Type 1 and 3 transitions for bead and block tasks across all three days of the study. These plots appear in Figure 3 and do not appear to reveal any consistent trend across days. Again, these data are for no-belt trials only, but it may be recalled that the analysis of variance failed to find that belt condition was statistically related to experience across days.

Figure 3. Normalized Reach Distances Across Days for Task and Condition



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 2-3 hours per day, while a second group was not given the belts. There were eight subjects who took the belts home and 5 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 at any effect on Day 3 reaches

Analysis of Type 2 Reaches -- Mode Suppression

As the object to be grasped is placed beyond the subjects' Preferred Critical Boundary for arm and torso reach, each individual has, in effect, a choice amongst two types of reach. Either an intermediate, partially standing (Type 2) reach can be used, or the subject can go to immediately to fully standing (Type 3). The original work of Gardner et al., (1997) observed evidence of mode suppression; that is, the reduction in frequency of Type 2 reaches in the bead task as compared with the block task.

The present data clearly confirm Gardner's mode suppression effect. Figures 4 and 5 indicate the frequencies of each of the three types of reach as reach distance is increased. Data are plotted for Days, Task, and Condition. Examination of the data reveal that the partially standing reaches are much less frequent when the subject is required to reach for a bead. There are, however, no apparent differences in the effect across Days and whether or not subjects are wearing a belt. It should be also noted that the large variability in frequency of Type 2 reaches made it inappropriate to enter them as dependent variables into the analyses of variance.

Figure 4. Frequency of Type 1,2, and 3 Reaches –Day 2

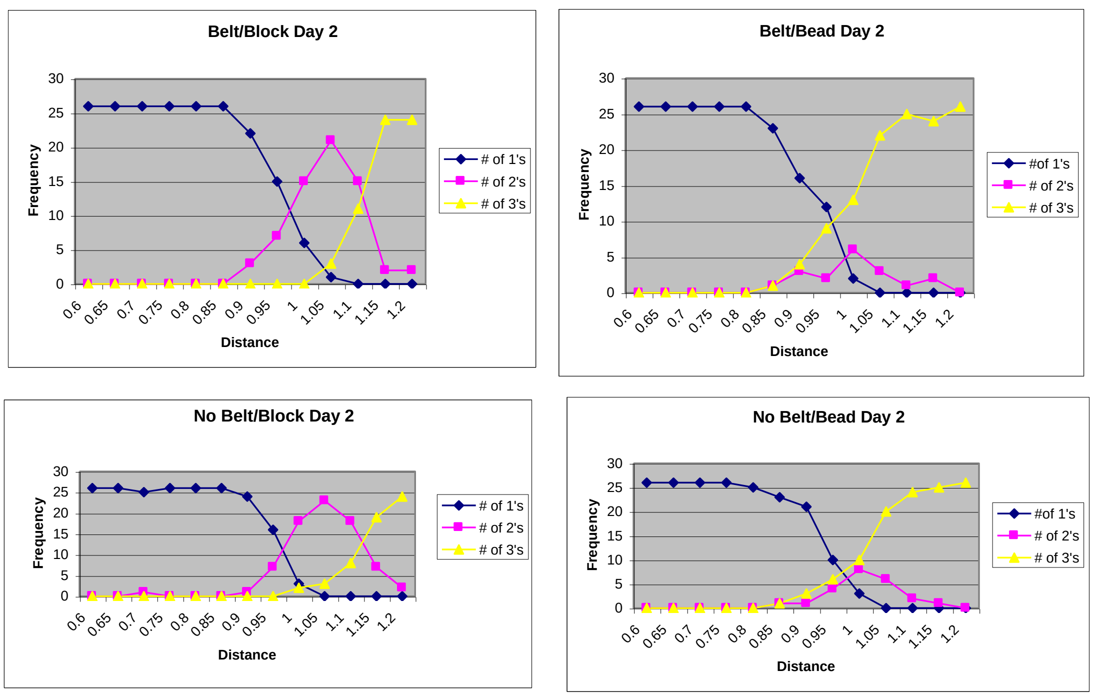
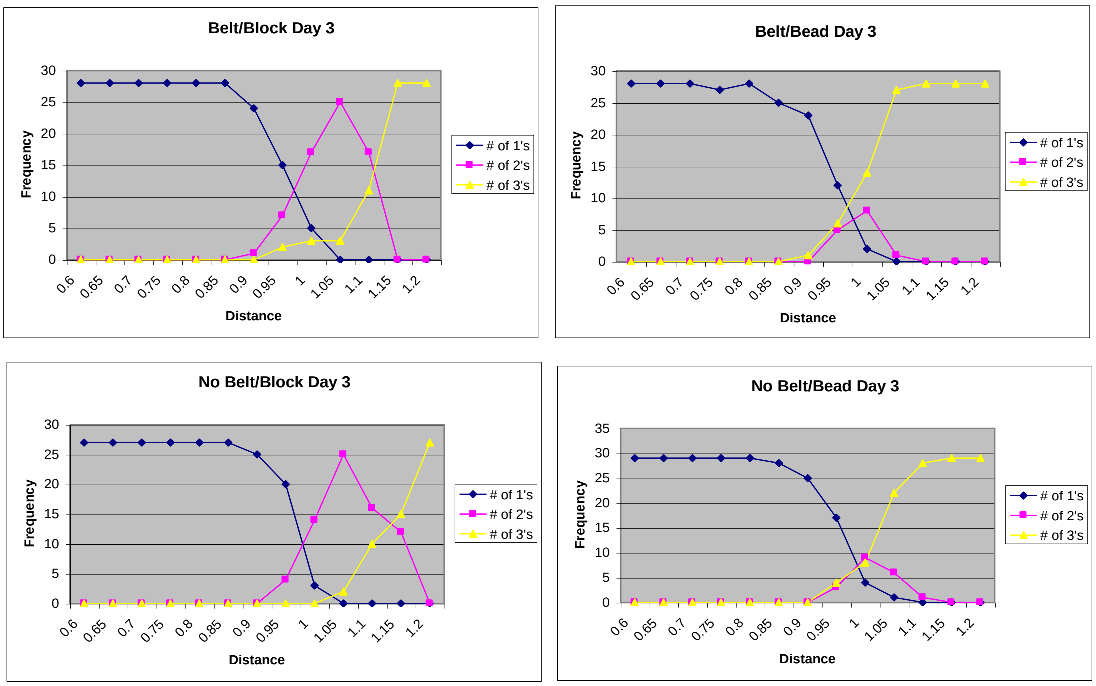


Figure 5. Frequency of Type 1,2, and 3 Reaches –Day 3



DISCUSSION

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. Hence, the belt seems to act to preserve a greater margin of safety--keeping the user from extreme ranges of motion. It is interesting, however, that this effect only seems to happen when the task requires a more difficult task (picking up a small bead with a needle) in which the posture had 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: (a) The bead task is more complex; there are actually two reach movements, one for the needle and the second for the bead. (b) The targets (needle and bead diameter) are much smaller. (c) Postural requirements for the hand are more precise—a precision grip rather a power grip is needed. Inherent in these task elements is a differential requirement for postural *stability*. 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, lead 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 (1999), 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. 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.

Finally, 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 a 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.

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