The Effect of Solid Ankle-Foot Orthoses on Movement Patterns Used in a Supine-to-Stand Rising Task

Background and Purpose. Within dynamical pattern theory, ankle motion can be proposed to be a control variable, and solid ankle-foot orthoses (SAFOs) can be considered a constraint to ankle movement. The purpose of this study was to examine the effect of SAFOs on movement patterns used to rise from the supine position to erect stance. Subjects. Thirty-nine nondisabled young adults, ranging in age from 20 to 28 years (X=22.7, SD=1.87), participated. Methods. Subjects were videotaped while rising from a supine position on a floor mat. Each subject performed 10 trials under each of four conditions: without SAFOs, right SAFO, left SAFO, and bilateral SAFOs. Movement patterns were described within three body components (ie, upper extremities, axial region, and lower extremities) by determining the mode and the incidence of each movement pattern under each condition. The subjects’ mode movement patterns in the no SAFO condition were compared with mode movement patterns in the SAFO conditions using McNemar tests. Results. Without SAFOs, subjects rose most commonly using a push and reach pattern of the upper extremities, a forward with rotation pattern in the trunk, and an asymmetrical squat in the lower extremities. Changes in the incidence of movement patterns occurred in all of the SAFO conditions when compared with the no SAFO condition. These changes resulted in more asymmetry when SAFOs were worn, and asymmetry was most notable in the axial region. Conclusions and Discussion. From a dynamic pattern theory perspective, ankle motion is a control variable for the supine-to-stand rising task. [King LA, VanSant AF. The effect of solid ankle-foot orthoses on movement patterns used in a supine-to-stand rising task. Phys Ther. 1995;75:952-964.]

Key Words: Movement patterns. Solid ankle-foot orthosis.

Dynamic pattern theory has been advanced as an approach to the understanding of coordinated movement. Within the framework of this theory, motor behavior emerges as a result of interaction among a variety of subsystems. These subsystems have been proposed to include among others, biological structures, such as the musculoskeletal system, the central nervous system, and body topology, as well as environmental factors termed constraints and affordances. Dynamic pattern theorists endeavor to describe complex motor behavior in simple mathematical terms, which they call order parameters (variables). An order parameter is a quantitative variable that characterizes the consistent spatiotemporal order in complex mo-
motor behavior. Researchers have used as order parameters mathematical expressions that portray complex phase relationships between two joints in a limb, or between limbs. For example, in recent studies, the relationship between infants' hip and knee angles during kicking and stepping have been used as order parameters.8

Having identified an order parameter (a variable), theorists then manipulate control parameters to evoke qualitatively different movement patterns. A control parameter is a variable that can be scaled to produce qualitative change in motor behavior. For example, speed can be increased to change a locomotor pattern from a walk to a run.1,4 The qualitative change would be evident as a change in the order variable.

Constraints and affordances are theoretical terms used to connote conditions that either limit or promote specific motor behaviors, respectively. Examples of a constraint could be a slippery walking surface or the wearing of a solid ankle-foot orthosis (SAFO). These conditions would be theorized to constrain or limit the motor behaviors that could be seen to emerge from the dynamic interaction among biological and environmental systems. Conversely, a 0.61-m-high (2-ft-high) stone wall allows sitting, and a ladder permits climbing. The wall and the ladder represent environmental affordances that promote the behaviors of sitting and climbing, respectively.

Movement patterns used to perform the supine-to-stand task have been described for three components of body action: upper extremities, axial region, and lower extremities.6,7 A set of movement pattern descriptions for each component capture the consistent spatiotemporal order observable in this task. Although these movement pattern descriptions are qualitative and not quantitative in nature, we suggest that these movement patterns can substitute for quantitative order variables to test certain aspects of dynamic pattern theory.

A major limitation of our qualitative approach is that fluctuation in movement patterns can be detected only at macroscopic levels of observable pattern shifts. Quantitative order variables, in contrast, as more sensitive measures, may convey increasing instability within a pattern that predicts qualitative movement pattern shifts. The practical limitations of contemporary technology, however, prevent widespread use of three-dimensional movement analysis needed to mathematically characterize actions such as the supine-to-stand movement.8

Within a dynamic pattern theoretical framework, we consider the movement pattern descriptions to represent the order variables for this task. We hypothesize that ankle motion is a control parameter (a variable) for the rising task. Solid ankle-foot orthoses may act as an external constraint limiting ankle motion and thus changing the movement pattern strategies used to rise to a standing position. The purpose of this study was to describe the effect of wearing SAFOs on movement patterns of nondisabled young adults when rising from a supine to a standing position. Supine-to-stand movement pattern descriptions6,7 were used to classify supine-to-stand movements and to determine whether the use of SAFOs resulted in qualitatively different patterns. The movement pattern descriptions were considered order variables. The primary question was: Would the upper-extremity, axial, and lower-extremity patterns exhibited when wearing a SAFO differ from patterns exhibited when not wearing a SAFO? A characteristic of normal functional performance is flexible use of movement patterns across a variety of environmental contexts. Understanding constraints and affordances for movement should ultimately help therapists design therapeutic programs that promote function.

**Method**

**Subjects**

A sample of convenience was recruited from the first-year class of physical therapist students at Temple University. Individuals were excluded who reported any physical impairments or medical conditions that might interfere with the ability to perform the rising task. Thirty-nine adults (29 female, 10 male), ranging in age from 20 to 28 years (X=22.7, SD=1.87), participated in the study.

**Design**

The study was conducted as a quasi-experimental, repeated-measures design.9 Subjects performed the rising task under four randomly ordered conditions: no SAFO, SAFO on the right leg, SAFO on the left leg, and SAFOs on both legs. Ten trials were performed in each condition.

**Instrumentation**

Subjects wore prefabricated 0.48-cm-thick (⅛-in-thick) SAFOs* during data collection. The SAFOs were sized small, medium, and large and were fitted using shoe size and subjects’ reports of comfort. During a pilot study, proximal anterior tabs designed to hold the lower leg in the SAFO were deemed uncomfortable by subjects. The lateral edges were therefore cut back to eliminate the tabs, and the Velcro® strap was sufficient to maintain proper leg position in the SAFO. The SAFOs were also trimmed proximal to the metatarsal heads. Subjects were asked to wear sneakers that would accommodate SAFOs.

Movement from a supine to a standing position was recorded using two video cameras mounted on tripods located approximately 6.01 m (20 ft) from the edge of a floor exercise mat. The cameras were positioned approximately perpendicular to two adjoining sides of the 1.2×2.4-m (4×8-ft) mat.

---


1. Velcro USA Inc, 406 Brown Ave, PO Box 5218, Manchester, NH 03108.

---

Physical Therapy / Volume 75, Number 11 / November 1995 953 / 27
The optical axes of the lens bisected the center of the mat at the height of 0.9 m (3 ft) above the floor. The zoom lens of the cameras was adjusted to maximize subject image. An information board in view of each camera displayed the subject number and trial number. Data were analyzed using a television monitor and a videocassette player that could play tapes in slow motion.

**Procedure**

Each subject signed an informed consent form before participation in the study. Prior to data collection, the study requirements were explained and any of the subjects' questions answered. Each subject performed 10 trials of the rising task in each of the four conditions, for a total of 40 trials. Subjects were not given an opportunity to accommodate to the orthotic devices prior to data collection. Random sequences of conditions were used for each subject. At the start of each trial, the subject lay supine in the center of the exercise mat and was instructed to stand up as fast as possible after the commands of “ready” and “go.” Subjects were requested to stand up quickly in order to minimize their conscious analysis of the form of their movements. Each subject took approximately 15 minutes to complete the 40 trials of rising. No attempts were made to standardize either the time of day of data collection or the amount of rest afforded each subject. Subjects self-paced their rest between trials and conditions. All trials were recorded on videotape.

**Data Reduction**

The first author was trained by the second author to classify movement patterns using videotapes of adult subjects obtained in a previous study of the rising task. The first author's ability to classify the movement patterns was tested in a randomly selected sample of 50 trials that both authors classified. When less than 90% agreement was found between the authors, decision rules were clarified while reviewing the videotaped performances that led to disparate ratings. Training was completed when the two authors attained 90% or greater agreement in their classification of those movement patterns.

After the first author had been trained, she then reduced all data obtained in this study by classifying all movement patterns observed within each body region for all trials of each condition. Descriptions of the upper-extremity (UE), lower-extremity (LE), and axial region (AX) movement patterns are presented in the Appendix. The recorded data were viewed using a videocassette player and television monitor. The data for UE movements were reduced using recordings from the foot view. The side-view videotapes were used to reduce data for the LE and AX patterns. When necessary, the alternative view was used to assist in classifying movements. The UE patterns were reduced first for trial 1 for all subjects under all conditions. This procedure was repeated until all 10 trials were reduced. The AX and LE patterns were reduced in the same way. This approach minimized within-subject rater bias.

**Reliability**

One hundred randomly selected trials were classified by the second author. The percentage of agreement between the two authors was calculated within each body region. Kappa statistics were then calculated as an expression of reliability of the ratings between the two authors. Reliability was determined between the authors to allow comparison of results with those of other studies completed by the second author. The coefficient of agreement (Kappa) between the two authors was .903 for UE patterns, .895 for LE patterns, and .903 for the AX region. The first author repeated classification of 100 randomly selected trials to test intrarater agreement. Percentages of intrarater agreement were 98% for the UE component, 96% for the AX region, and 99% for the LE component.

**Data Analysis**

The incidence of each movement pattern was calculated as a percentage of trials in each condition. Bar graphs were constructed to illustrate these data. Each subject's UE, LE, and AX region modal movement patterns were combined to present a profile of whole body action. McNemar tests were used to determine whether the subject's regional modal movement patterns changed in the three SAFO conditions compared with the no SAFO condition. Three tests were performed, one for each of the three movement components. The McNemar test was selected because it is designed to detect qualitative changes in related samples with repeated measures. The conditions compared were (1) no SAFO and right SAFO, (2) no SAFO and left SAFO, and (3) no SAFO and both legs in SAFOs. The alpha confidence level of .05 was used for all tests. Individual subjects were excluded from a McNemar test when they demonstrated a bimodal performance in any one of the conditions compared.

**Results**

**Profiles of Movement Patterns Under Each Condition**

Within this sample of 39 adults, nine different combinations of component action appeared across the 390 trials performed without a SAFO. Six of these nine combinations were also observed in all three SAFO conditions. In the right, left, and bilateral SAFO conditions, 9, 8, and 11 different movement pattern profiles were observed, respectively. Though the combinations of component action observed were similar across conditions, there were differences in their relative frequencies. The incidences of these combinations across conditions using each subject's mode performance are presented in the Table.

The most common form of rising varied across conditions. Without a SAFO, subjects commonly rose by pushing and reaching with the UEs, moving the AX region forward with rotation toward a sitting position and using an asymmetrical, wide-based LE squat pattern. This combination of movement patterns, illustrated in Fig-
Table. Movement Component Profiles of Whole Body Actiona

<table>
<thead>
<tr>
<th>Profiles (UE/AX/LE)</th>
<th>No. of Subjects</th>
<th>No SAFO</th>
<th>Right SAFO</th>
<th>Left SAFO</th>
<th>Both SAFOs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1—push and reach/forward with rotation/asymmetrical squat</td>
<td>19</td>
<td>11</td>
<td>15</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2—push and reach/partial rotation/asymmetrical squat</td>
<td>2</td>
<td>15</td>
<td>12</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>3—symmetrical push/symmetrical/asymmetrical squat</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4—push and reach/forward with rotation/symmetrical squat</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5—push and reach/symmetrical/asymmetrical squat</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>6—symmetrical push/symmetrical/symmetrical squat</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>7—push and reach/partial rotation/symmetrical squat</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8—push and reach to bilateral push/partial rotation/asymmetrical squat</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9—push and reach/symmetrical/symmetrical squat</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Subjects with bimodal profiles are excluded. (UE=upper-extremity component, AX=axial component, LE=lower-extremity component, SAFO=solid ankle-foot orthosis.)

Figure 1. Most common movement pattern profile seen in no solid ankle-foot orthosis and left solid ankle-foot orthosis conditions: upper-extremity component—push and reach, axial region component—forward with rotation, lower-extremity component—symmetrical, wide-based squat.

This profile included the AX partial rotation pattern.

Incidence of Movement Patterns Under Each Condition

Upper extremity. The most common pattern in all SAFO conditions was the push and reach movement pattern. Figure 3 illustrates the incidence of UE movement patterns across trials for each of the conditions studied. In the SAFO conditions, there were reduced frequencies of the UE symmetrical push pattern compared with that seen in the no SAFO condition. The right SAFO and bilateral SAFO conditions resulted in the appearance of the push pattern.

SAFO was worn and when both SAFOs were worn differed from the no SAFO pattern in trunk action (Fig. 2).
Lower-extremity patterns. The most common LE movement pattern in all conditions was the asymmetrical, wide-based squat. In the no SAFO and unilateral SAFO conditions, only two patterns were seen: the asymmetrical, wide-based squat and the symmetrical squat. Figure 5 illustrates the incidence of each LE pattern across trials for each of the conditions. The incidence of the symmetrical pattern was reduced in all SAFO conditions when compared with no SAFO trials. The majority of subjects did not vary LE movement patterns across the 10 trials. In both the no SAFO and right SAFO conditions, 12 subjects’ movement patterns fluctuated between the symmetrical and asymmetrical squat patterns. In the left SAFO condition, 5 subjects varied between two patterns. Fourteen of the subjects fluctuated between two patterns in the bilateral SAFO condition. In the bilateral SAFO condition, 3 subjects used the half-kneel pattern in a total of 6 trials.

Changes in Subjects’ Movement Patterns Under Each SAFO Condition

Individuals varied their mode movement patterns in response to the application of SAFOs. Twenty-two subjects wearing a right SAFO changed mode pattern of at least one component when compared with the no SAFO condition. Twenty subjects demonstrated a change between the no SAFO condition and left SAFO condition, and 30 subjects changed in at least one component when the no SAFO and bilateral SAFO conditions were compared. Changes in each component will be discussed.

Upper extremity. The McNemar test was used to compare the number of subjects demonstrating a change in mode movement pattern under two conditions. Figure 6a presents the comparison of the change in UE patterns between the no SAFO and right SAFO conditions. Two of the 39 subjects were excluded from this test because they demonstrated a bimodal performance. The contingency table (Fig. 6a) shows that 26 individuals demonstrated the push and reach pattern as their mode pattern under both conditions. Four individuals demonstrated a symmetrical push pattern consistently under both conditions. One individual, however, demonstrated the push and reach pattern as a mode performance in the no SAFO condition and the push and reach to bilateral push pattern in the right SAFO condition. The McNemar test, based on probabilities of a chi-square distribution, revealed that the number of individuals who changed UE patterns from the no SAFO condition to the right SAFO condition (Fig. 6a) was not significant ($P \leq .75$). Thirty-six individuals were available for the comparison of the no SAFO and left SAFO conditions. Four individuals changed from a symmetrical reach pattern in the no SAFO condition to the push and reach pattern when the no SAFO and left SAFO conditions were compared (Fig. 6b). This represented a change ($P \leq .025$). Eight individuals changed mode pattern between the no SAFO and bilateral SAFO conditions (Fig. 6c). Two individuals were excluded from this comparison due to a bimodal performance.

Axial region. Contingency tables for McNemar tests comparing each SAFO condition with the no SAFO condition are shown in Figure 7. Data from all 39 subjects were used in these comparisons, with the exception of the no SAFO and left SAFO comparison in which 37 subjects were available for study. Twenty subjects changed their
Figure 3. Upper-extremity movement patterns: A—push and reach to bilateral push; B—push and reach; C—symmetrical push; D—bilateral reach; E—push and reach with thigh push. SAFO=solid ankle-foot orthosis. There were 390 trials for all conditions except for the right SAFO condition, which had 389 trials.

mode AX movement pattern when wearing a right SAFO when compared with the no SAFO condition ($P \leq 0.05$). Fourteen subjects were found to have changed their mode AX movement pattern when the left SAFO and no SAFO conditions were compared. Twelve subjects adopted a partial rotation pattern, abandoning the forward with rotation pattern. Two additional subjects shifted to the forward with rotation pattern from the symmetrical pattern. These changes in mode AX movement patterns resulted in a difference between the no SAFO and left SAFO conditions ($P \leq 0.05$). In the bilateral SAFO condition, 30 subjects demonstrated increased asymmetry in the mode movement patterns of the AX region compared with the no SAFO condition. Twenty-eight subjects adopted a partial rotation pattern. Twenty-four of these subjects changed from the forward with rotation pattern, and 4 subjects changed from the symmetrical pattern. Two subjects changed from the symmetrical pattern to a forward with rotation pattern. The number of individuals ($n=30$) changing mode patterns between the bilateral SAFO and no SAFO conditions was significant ($P \leq 0.01$).

**Lower extremity.** Figure 8 presents the McNemar test results for changes in mode LE movement patterns. In both the no SAFO versus right SAFO condition and the no SAFO versus left SAFO condition, 38 subjects' data were available for analysis. In the no SAFO versus both SAFOs condition, 37 subjects' data were used in the comparison. Eleven subjects changed their mode patterns in the right SAFO condition when compared with the no SAFO condition. Ten subjects switched to the asymmetrical squat pattern from the symmetrical squat pattern. One subject changed from the asymmetrical squat pattern to a symmetrical squat pattern. Ten subjects changed modal patterns in the left SAFO condition, 9 of whom shifted from the asymmetrical squat pattern to the asymmetrical squat pattern. One subject moved from the asymmetrical squat pattern to the symmetrical squat pattern. Thirteen subjects changed modal patterns in the bilateral SAFO condition. Twelve of these subjects changed from a symmetrical squat pattern to an asymmetrical squat pattern, and 1 subject shifted from the asymmetrical squat pattern to the symmetrical squat pattern.

**Summary**

The added constraint of wearing a SAFO unilaterally or on both LEs produced differences in the relative frequencies of the movement patterns. In the SAFO trials, there was an increased incidence of asymmetrical movement patterns in all three movement components compared with the no SAFO condition. No subject demonstrated symmetrical patterns across all three components in any SAFO condition. The McNemar tests compared the number of subjects demonstrating a change in mode movement pattern from the no SAFO condition to each of the SAFO conditions. In the UE component, differences were found between the no SAFO condition and the left and bilateral SAFO conditions. There was no difference in subjects' movement pattern modes between the no SAFO and right SAFO conditions. For the AX and LE components, there were changes in movement pattern modes between all of the SAFO conditions and the no SAFO condition. Approximately one half of the subjects demonstrated increased asymmetry in at least one component.
SAFO conditions prior to performing the no SAFO trials may have influenced movement patterns observed in the no SAFO condition. Examining the randomized condition order revealed that only 2 subjects had a totally symmetrical profile in no SAFO trials occurring after SAFO conditions.

Another factor may be age. A study of adolescents rising to a standing position described 15-year-old subjects as having a comparable proportion of subject mode symmetrical profiles to the young adult study, but there was a decrease in symmetrical body profiles in the 19-year-old subjects (7 of the 32 subjects). The SAFO study's subjects' mean age was closer to the 19-year-old age group's mean age than the young adult mean age of 28.6 years, so we might predict a smaller proportion of subjects using total body symmetry.

Fatigue may also have been a factor, as subjects stood up a total of 40 times in this study compared with the 10 trials in the young adult study. No individual had a totally symmetrical profile in his or her last condition. Due to the relatively small sample sizes, the possibility that the differences in total body symmetry occurrence are within normal subject variance cannot be excluded.

Influence of the Orthoses

The SAFOs' influence on movement patterns appears greatest at the point of weight transfer from the buttocks to the feet. The ankles must be plantar flexed sufficiently to allow the soles of the feet to contact the floor and then dorsiflex as the individual moves weight forward off the buttocks onto the feet when assuming the squatting position. Therefore, ankle motion appears to be crucial when transferring weight from the buttocks to the feet when moving from a sitting to a squatting position. The SAFOs appear to have prevented these ankle motions and contributed to the emergence of compensatory strategies.

When one SAFO was worn, subjects often chose to keep that leg extended

Figure 4. Axial region movement patterns: A—full rotation, abdomen down; B—full rotation, abdomen up; C—partial rotation; D—forward with rotation; E—symmetrical. SAFO=solid ankle-foot orthosis. There were 390 trials for all conditions except the right SAFO condition, which had 389 trials.

Discussion

Baseline Performance

Our first objective was to describe the effect of wearing SAFOs on movement patterns used to rise from a supine to a standing position. We begin with the baseline trials in which SAFOs were not worn. The movement pattern profiles used in the no SAFO condition were different than those seen in a previously reported study of non-disabled adults rising to a standing position. In order to compare the two studies, we merged the originally reported symmetrical squat with balance step pattern into the symmetrical squat pattern. A major difference was that 11 of the 32 young adults exhibited total body symmetry compared with just 4 of this study's 39 subjects in the no SAFO condition. In the previous study of young adults, 10 different mode movement profiles were identified compared with just 6 observed in our no SAFO condition. Within-subject variability was similar between the two studies. Differences in incidence of symmetrical body profiles may be related to several contributing factors. Rising to a standing position in the
in front of them with just the heel contacting the floor until beginning to rise from an asymmetrical squat position. At this point, they would often bring their leg back beside the leg bearing weight. Trunk rotation occurred as subjects attempted to shift weight forward off their buttocks onto their feet. Associated with this LE pattern was a tendency for subjects to rotate the trunk away from the SAFO side. The UE opposite the SAFO side often pushed against the floor while the ipsilateral UE reached forward until subjects accepted weight on their feet.

When wearing both SAFOs, subjects appeared to compensate by medially rotating their hips to achieve a widened base of support. This action brought just the subjects' toes in contact with the floor, and they appeared unstable. Three subjects medially rotated one hip to such a degree that their LE pattern shifted from an asymmetrical, wide-based squat into a half kneel pattern. As in the unilateral SAFO condition, subjects rotated their trunks when shifting their weight onto their feet. Trunk rotation seemed to increase when subjects were having an especially difficult time with weight transfer. The most common AX pattern in the bilateral SAFO trials was partial rotation. This pattern reflects a greater degree of trunk rotation than the forward with rotation pattern, which was seen more commonly in the no SAFO condition. An exception to this very common strategy in the bilateral SAFO condition occurred when subjects compensated with a very wide-based, medially rotated squat. In this instance, they exhibited less trunk rotation. Indeed, three of these subjects moved with a symmetrical AX pattern. Across all of the SAFO conditions there was a tendency for subjects to take steps or hop to regain their balance after reaching a standing position.

The second objective of this study was to determine whether subjects changed movement patterns between SAFO conditions and the no SAFO condition. We found that movement patterns changed in all body regions except for the UE component in the right SAFO condition. The majority of movement pattern transitions were from symmetrical to more asymmetrical patterns in all three movement components. The AX region was most sensitive in registering changes in the SAFO conditions from the no SAFO condition. In the UE component, less than 25% of the subjects changed from their no SAFO movement patterns in SAFO conditions, whereas the AX region registered change in over 75% of the subjects' patterns in the bilateral SAFO condition.

Utility of Dynamic Pattern Theory

Our third objective was to interpret this study's results within a dynamic pattern theoretical framework. The movement pattern descriptions were sensitive to qualitative changes in movement strategies in the SAFO conditions compared with the no SAFO condition. Thus, the movement pattern descriptions were successfully used as order variables.

The finding that ankle motion during weight transfer is a critical determinant of emergent patterns supports the view of ankle motion as a control variable for the task of rising from a supine to a standing position. Dynamic pattern theory portrays the stability of movement patterns by reference to attractors.1 An attractor is
Figure 6. Contingency tables for McNemar’s tests of upper-extremity modal patterns: (a) no solid ankle-foot orthosis (SAFO) versus right SAFO; (b) no SAFO versus left SAFO; (c) no SAFO versus both SAFOs. Movement patterns: A—push and reach to bilateral push; B—push and reach; C—symmetrical push. In the no SAFO versus right SAFO McNemar test, two subjects were not included due to bimodal performance in one of the conditions. Three subjects were not included in the no SAFO versus left SAFO McNemar test and two subjects were not included in the no SAFO versus bilateral SAFO test due to bimodal performance.

<table>
<thead>
<tr>
<th></th>
<th>Right SAFO Pattern</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No SAFO Pattern</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>26</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>$\chi^2$=1.667</td>
<td>$P=0.75$</td>
<td>n=37</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Left SAFO Pattern</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No SAFO Pattern</td>
<td>B</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>30</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>$\chi^2$=6.25</td>
<td>$P=0.025$</td>
<td>n=36</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Both SAFO Pattern</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No SAFO Pattern</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>$\chi^2$=8</td>
<td>$P=0.05$</td>
<td>n=37</td>
<td></td>
</tr>
</tbody>
</table>

The asymmetrical, wide-based squat LE pattern and the asymmetrical push and reach UE pattern could be considered strong attractors. The asymmetrical push and reach UE pattern appeared to represent the pattern most resistant to change. Only 3 of the 30 subjects who used the push and reach UE pattern in the no SAFO condition changed patterns in one of the SAFO conditions. The least amount of intra-subject pattern fluctuation across trials was observed in the push and reach UE pattern across all conditions. The low within-subject variability across trials suggests a strong attractor.

In contrast, symmetrical patterns in the rising task could be considered “shallow-well” or weak attractors. The symmetrical patterns were very vulnerable to manipulation of the control variable of ankle motion. The movement patterns of the AX region did not have any strong attractors. There was a high incidence of intra-subject pattern fluctuation among three patterns in each condition. This finding reflects pattern instability and weak attractors.

Motor behavior is considered an emergent property of subsystems’ interaction within an environmental context. In this study, we added a constraint to the system by limiting ankle motion. Ankle motion appears to be a control variable for this task, but ankle motion alone did not cause the pattern changes. Subject characteristics such as body topology, flexibility in other body regions, and coordination interplay with ankle motion in this task. Each subject has a repertoire of emergent movement patterns that can be used to accomplish this task. Whether the SAFOs constrained this repertoire for any subject is not known. One consistent finding was that unlike the no SAFO condition, in the SAFO conditions there were no instances of symmetrical movement patterns across all three body components. Therefore,
Figure 7. Contingency tables for McNemar's tests of axial region modal patterns: (a) no solid ankle-foot orthosis (SAFO) versus right SAFO; (b) no SAFO versus left SAFO; (c) no SAFO versus both SAFOs. Movement patterns: C—partial rotation; D—forward with rotation; E—symmetrical. All subjects were included in the McNemar tests except for in the no SAFO versus left SAFO condition, where two subjects had bimodal performance in the left SAFO condition.
motion appears to be a necessary, but not sufficient, condition for the symmetrical profile movement to occur.

Patients with reduced ankle motion may also have restricted movement pattern repertoires in this task. Often in clinical practice, however, restrictions in ankle motion are accompanied by balance impairments and by deficits in the production, sequencing, and control of force. Much work remains to further clarify those bodily and environmental systems that are necessary for different strategies used to perform this task in both patient and nonpatient populations. We suggest that compensatory movement strategies should be seen as successful solutions to motor problems, rather than in a negative context. Ideally, we should plan therapy to include a variety of environmental contexts and manipulation of control variables to promote flexible use of movement pattern strategies in functional tasks.

Finally, the movement pattern descriptions used in this study may not be sensitive enough for use in studies using a motor learning paradigm. There were subtle within-movement pattern differences noted between earlier and later trials of a given subject that were obscured by this qualitative classification scheme. For example, a few subjects wearing both SAFOs demonstrated early variability in foot placement until one preferred stance emerged and was used consistently. A motor learning research paradigm would seem to be better served with a quantitative analysis, particularly for examination of differences in foot placement used during the rising task.

Conclusions

Ankle motion can be considered a control variable for the task of rising from a supine position on the floor to a standing position. Solid ankle-foot orthoses constrain ankle motion during the task of rising from a supine to a standing position. The constraint is most apparent when transferring weight from the buttocks to the feet during the rising task. Compensatory

Figure 8. Contingency tables for McNemar's tests of lower-extremity modal patterns: (a) no solid ankle-foot orthosis (SAFO) versus right SAFO; (b) no SAFO versus left SAFO; (c) no SAFO versus both SAFOs. Movement patterns: D—asymmetrical squat; E—symmetrical squat. One subject was not included in both the no SAFO versus right SAFO and no SAFO versus left SAFO McNemar tests due to bimodal performance in one condition. Two subjects had bimodal performances in the no SAFO versus bilateral SAFO test and were not included.
strategies emerge to accomplish this weight transfer when ankle motion is restricted. These strategies are characterized by increased asymmetry in all three movement components when SAFOs are worn on one or both legs. The AX region is most sensitive to the constraint of ankle movement in this task.

References


8 VanSant AF. Analysis of movement dysfunction. Presented at the Eugene Michaels Forum at the American Physical Therapy Association Annual Conference; February 5, 1993; San Antonio, Tex.


10 Luchinger SK. Component Movement Patterns of Two Groups of Older Adults in the Task of Rising to Standing From the Floor. Richmond, Va: Virginia Commonwealth University; 1989. Master’s thesis.


12 Cohen J. Weighted Kappa: nominal scale agreement with provision for scaled disagreement on partial credit. Psychol Bull. 1968;70:213—220.


Appendix

Movement Pattern Descriptions

Upper-Extremity Component Developmental Categories

Step 1—Push and Reach to Bilateral Push. One hand is placed on the support surface beside the pelvis. The other arm reaches across the body, and the hand is placed on the surface. Both hands push against the surface to an extended elbow position. The arms are then lifted and used for balance.

Step 2—Push and Reach. One or both arms are used to push against the support surface. If both arms are used, there is asymmetry or asynchrony in the pushing action or a symmetrical push gives way to a single arm push pattern.

Step 3—Symmetrical Push. Both hands are placed on the surface. Both hands push symmetrically against the surface prior to the point when the arms are lifted synchronously and used to assist in balance.

Step 4—Bilateral Reach. The arms reach forward, leading the trunk, and are used as balance assists throughout the movement.

Step 5—Push and Reach With Thigh Push. One or both arms are used to push against the support surface. If both arms are used, there is asymmetry or asynchrony in the pushing action or a symmetrical push gives way to a single arm push pattern. The other arm is then placed on one knee and pushes, assisting in extension of the trunk or legs to the vertical.

Step 6—Push and Reach to Bilateral Push With Thigh Push. One hand is placed on the support surface beside the pelvis. The other arm reaches across the body, and the hand is placed on the surface. Both hands push against the surface to an extended elbow position. One or both arms are then lifted and placed on the thighs and push, assisting in extension of the trunk or legs to vertical.

Axial Component Developmental Categories

Step 1—Full Rotation, Abdomen Down. The head and trunk flex and rotate until the ventral surface of the trunk contacts the support surface. The pelvis is then elevated to or above the level of the shoulder girdle. The back extends up to the vertical, with or without accompanying rotation of the trunk.

Step 2—Full Rotation, Abdomen Up. The head and trunk flex and/or rotate until the ventral surface of the trunk faces, but does not contact, the surface. The pelvis is then elevated to or above the level of the shoulder girdle. The back extends from this position up to the vertical, with or without accompanying rotation of the trunk.

Step 3—Partial Rotation. Flexion and rotation bring the body to a side-facing position with the shoulders remaining above the level of the pelvis. The back extends up to the vertical, with or without accompanying rotation.

Step 4—Forward With Rotation. The head and trunk flex forward with or without a slight degree or rotation. Symmetrical flexion is interrupted by rotation or extension with rotation. Flexion with slight rotation is corrected by counterrotation in the opposite direction.

Step 5—Symmetrical. The head and trunk move symmetrically forward past the vertical; the back then extends symmetrically to the upright position.
Appendix. (continued)

Lower-Extremity Developmental Component Categories

Step 1—Kneel. Both legs are flexed toward the trunk and rotated to one side. A kneeling pattern is assumed. One leg is then flexed forward to assume half kneeling. The forward leg pushes into extension as the opposite leg moves forward and extends.

Step 2—Jump to Squat. The legs are flexed and rotated to one side. Both legs are then lifted simultaneously off the support surface and derotated. The feet land back on the surface, with hips and knees flexing to a squat or semisquat position. The legs then extend to the vertical.

Step 3—Half Kneel. Both legs are flexed toward the trunk as one or both legs are rotated to one side. A half kneeling pattern is assumed. The forward leg pushes into extension as the opposite leg moves forward and extends.

Step 4—Asymmetrical Wide-Based Squat. One or both legs are flexed toward the trunk, assuming an asymmetrical, crossed-leg or wide-based squat. Medial (internal) rotation of the hips may cause the feet to be placed on either side of the pelvis. Asymmetry of hip rotation is common. The legs push up to an extended position. Crossing or asymmetries may be corrected during extension by stepping action.

Step 5—Symmetrical Squat. The legs are brought into flexion with the heels approximating the buttocks in a narrow-based squat. Stepping action may be seen during assumption of the squat, or balance steps (or hops) may follow symmetrical rise.

PROJECT FOCUS '94:
Physical Therapy Treatment Effectiveness for Older Persons

Almost 80% of babies born today will live to see their 65th birthday, compared with only 30% 50 years ago. Today, life expectancy is 78.5 years for women and 71.8 years for men.

In conjunction with the White House Conference on Aging, PROJECT FOCUS '94 was a forum created by the Foundation for Physical Therapy to bring researchers, clinicians, and educators together to discuss the challenges facing our aging society.