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PDF issue: 2025-07-02

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(Citation)
Bulletin of allied medical sciences Kobe : BAMS (Kobe), 9:61-70

(Issue Date)
1993-12-24

(Resource Type)
departmental bulletin paper

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/80070398

A Kinesiological Study of Increased Trunk Flexion in Rising Motion from a Seated Position

Toshihiko Yoneda, Toshiaki Muraki and Yoshio Taketomi

Rising motion from a seated position is often disturbed by musculoskeletal or neurological disorders. Physical and occupational therapists instruct patients with rising motion disorder to exercise with their trunks bending deeply. Twenty healthy males were selected for this study. The authors analyzed an ordinary rising motion and a special rising motion with the trunk bending kinetically and kinematically by means of force platform, electromyogram and video motion analysis method. The findings suggested that the way of rising motion would assist anterior shift of the center of gravity, decrease the knee joint moment as the knee extends, and diminish activities of the knee extensors (the quadticeps femoris muscle). It is considered useful as a training method for the patients with difficulty in rising from a chair. However, it is also pointed out as a mechanically inefficient motion due to the increases of both hip joint moment and activities of the hip extensors. Therefore, the advantages and disadvantages of this motion should be taken into cosideration in treating patients with rising motion disorder.

Key Words
Rising motion,
Increased trunk flexion,
Kinesiology,
Kinetics,
Kinematics.

INTRODUCTION

Sequential rising motion from sitting position consists of important components of various fundamental motions such as standing up from lying position and walking from sitting on a chair. This motion is considered to be a key motion. In many disorders of locomotive systems, therefore, this rising motion is always impaired. When patients have difficulty in rising from a seated position due to stroke, musculoskeletal disorders of the leg, Parkinsonism and disuse syndrome, physical and occupational therapists usually instruct them to increase forward lean of the trunk in rising motion. It is considered to facilitate smooth execution of the motion by shifting the center of gravity anteriorly. Those patients sometimes come to perform rising smoothly through practice of increased forword lean of the trunk. However, it has not been discussed whether rising motion with incresed trunk flexion is a mechanically efficient motion. The purpose of this study is to clarify kinesiological meaning of the rising motion with increased trunk flexion.

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SUBJECTS AND METHODS

Twenty healthy males without any musculoskeletal or neurological disorders were examined. Age at examination was 24.6 years old on an average (range:20-37 years). Average height and weight wrer 171.6 cm and 64.0 kg, respectively.

The analysis of rising motion was performed by means of a force platform, surface electromyogram and video motion analysis system (Figure 1). Two different conditions of rising postures were measured, 1) ordinary rising posture in which the subject feel easiest to stand up (Condition 1), and 2) rising with increased trunk flexion (Condition 2). The seat level was set as the same height as the length from the tibial plateau to the sole.

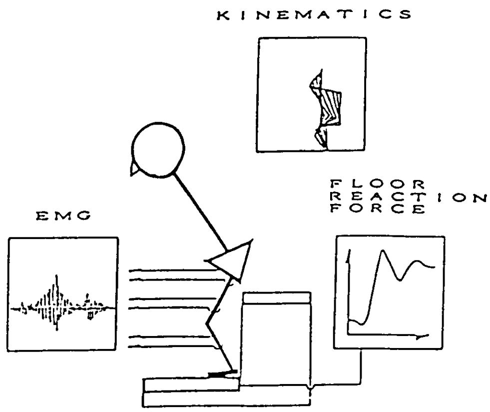

Figure 1. Method of measurement: Floor rection force was measured with a force platform under the left foot. Firing of six muscles of the left lower extremity (the tibialis anoterior, the lateral head of the gastrocnemius, the rectus femoris, the vastus medialis, the long head of the biceps femoris and the gluteus maximus muscles) was picked up by bipolar surface electrodes. Kinematics of the sit-to-stand movement was examined by a video motion analyzer system.

A force platform was placed on the seat to measure the timing of the buttocks leaving off the seat (buttocks off: BO). The other force platform was placed under the subject's foot to evaluate the functional extension of his leg. Schema of floor reaction force in rising motion was shown in Figure 2. The kinetics of the motion was studied by means of force platform (Kistler 9281B). The subject was instructed to stand up from a sitting position with one foot (mainly left foot) placed on the force platform

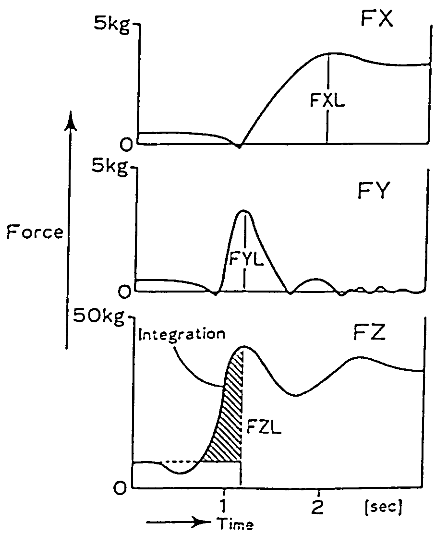

Figure 2. Schema of floor rection force in rising motion. FX: lateral component, FY: anterior-posterior component, Fz: vertical component, FXL: peak value in FX, FYL: peak value in FY, FZL: peak value in FZ, Striped part of FZ curve: integrated value of FZ from onest of the motion to the peak value which is considered to reflect extent of work in the motion.

and both feet were not placed simultaneously on the force platform, because the data would be disturbed by counterbalancing lateral components of the floor reaction force. The lateral (FX), anteroposterior (Fy) and vertical (Fz) components of the floor reaction force were picked up from the data, from which the center of pressure was calculated by a microcomputer (NEC PC9801F).

Electromyogram from the tibialis anterior, the lateral head of the gastrocnemius, the rectus femoris, the vastus medialis, the long head of the biceps femoris and the gluteus maximus muscles was taken by bipolar surface electrodes and recorded telemetrically by a pen recorder. The onset and end of firing, and peak voltage of muscle contraction in each muscle and in each condition, were measured and analysed (Figure 3).

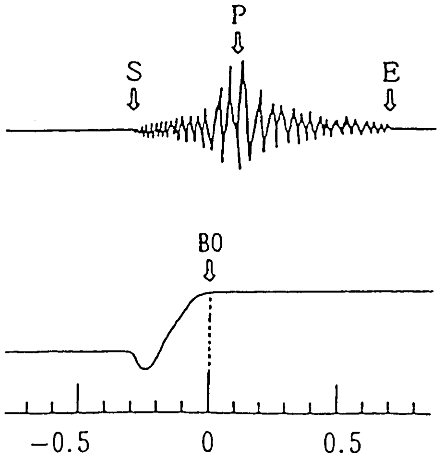

Figure 3. Analysis of surface electromyogram. S: start of firing, E end of firing, P: time at peak amplitude, BO: buttocks off

Kinematic analysis of the sequential motion was carried out by means of the Video Action Tracer (NAC VAT) and the Motion Analyzer (NAC Sportias). For video recording, light-reflecting markers were placed on the main reference points of he left side of the subject ; the top of the head, the ear, the acromion, the major trochanter, the knee joint, the ankle joint, the fifth metatarsal head and the cal-

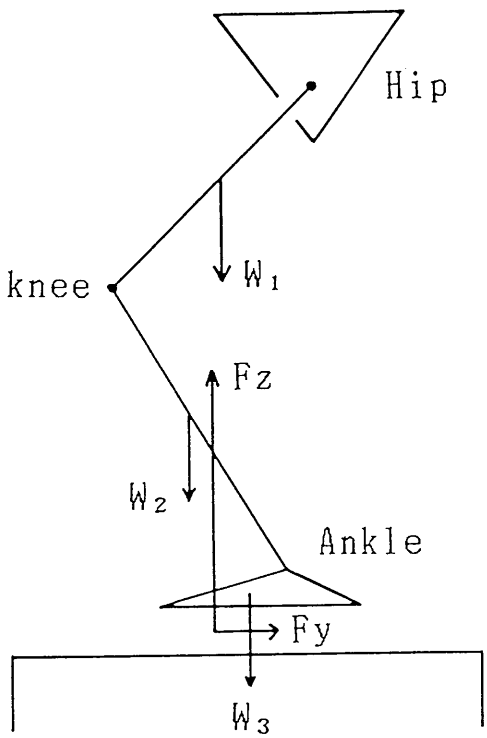

Figure 4. Calculation of joint moment at the hip, knee and ankle were performed by using floor reaction force, weight of each part of the leg and moment arm about each joint center
Fz: vertical component of floor reaction force
Fy: anterior-posterior component of floor reaction force
W1, W2,W3: weight of the thigh, shank and foot respectively for one side leg.

caneus. The joint angles and angle velocities of the hip, knee and ankle joint were measured by the motion analysis system.

Electromyographic, video and force platform recordings were all synchronized at the onset of measuring floor reaction force by using a strobo signal for the video camera and by marking electrically on the electromyogram.

Joint moments at the hip, knee and ankle were calculated from floor reaction force, weight of each part of the leg and moment arm about each joint center (figure 4). The calculating formula were as follows;

The hip joint moment: Mh

Mh = Fz*a (Fz) − Fy*a (Fy) − W1*a (W1) − W2*a (W2) − W3*a (W3)

The knee joint moment: Mk

Mk = Fz*b (Fz) + Fy*b (Fy) − W2*b (W2) − W3*b (W3)

The ankle joint moment: Ma

Ma = Fz*c (Fz) − Fy*c (Fy) − W3*c (W3)

where,

a (X): moment arm of x about the center of hip joint

b (X): moment arm of x about the center of hip joint

c (X): moment arm of x about the center of hip joint

Fz: vertical component of floor reaction force

Fy: anterior-posterior component of floor reaction force

W1, W2, W3: weight of the thigh, shank and foot respectively for one leg.

RESULTS

1) Floor reaction force

The floor rection force in ordinary standing-up motion was shown in Figure 5. The vertical component of floor reaction force showed two-peak pattern. The first peak reflected increased weight loading at the buttocks-off phase and the second peak appeared when the hip and knee joint were fully extended at the end of the motion.

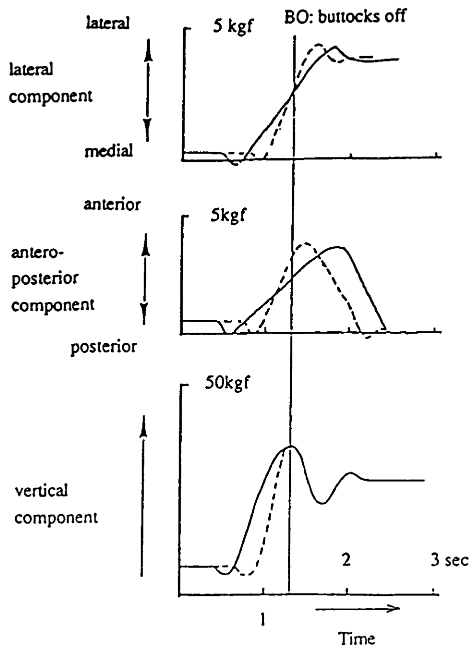

Figure 5. Patterns of floor reaction force in ordinary rising (broken line) and rising with increased trunk flexion (continous line).

In the sit-to-stand motion from a chair with increased trunk flexion, the time to perform the motion was prolonged, and the floor reaction force pattern was enlarged to the temporal direction of abscissa, while to the ordiante direction it did not show any distinct difference (Figure 5). The peak vertical component value (as percent of body weight) was 59.8 ± 7.0% in ordinary rising, while 60.1 ± 5.31% in rising motion with increased trunk flexion, which did not express significant difference ($p > .8$). The integrated vertical component of floor reaction force from onset of motion to the first peak showed 6.31 ± 3.32 [kgf-sec] in the ordinary rising motion. In the rising motion with increased trunk flexion, the integrated value demonstrated 10.01 ± 4.26 [kgf-sec]. Statistically significant difference was found ($p < .05$).

2) Center of pressure trace

Figure 6 indicated the center of pressure trace in rising motion within a sole and within a supporting base,

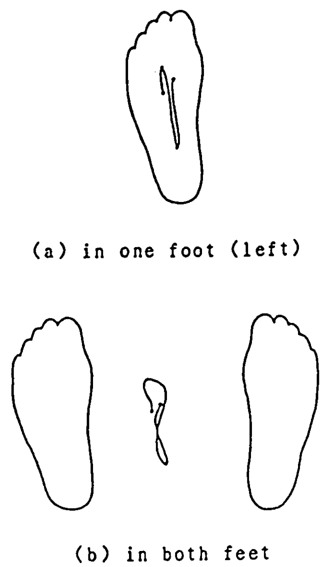

Figure 6. Examples of the center of pressure trace.
(a) within a sole
(b) within a supporting base (both feet)

namely, between both feet.

An difference of the-center-of-pressure trace was not found between right foot and left foot placed on the force platform. The traced length of the center of pressure during the motion was 169 ± 45.7 mm in the ordinary standing-up motion, and 237 ± 46.0 mm in the sit-to-stand motion with increased trunk flexion. The difference was statistically significant ($p < .01$).

3) Kinematics

Figure 7 showed joint angle changes at the hip, knee and ankle in the ordinary rising motion (continuous line) and in the rising motion with increased trunk flexion (broken line of the hip and knee). The hip joint flexed during first one third of the period from start to end. It reached the maximum flexion at buttocks-off phase, after which it began to extend. The knee joint began to extend immediately after buttocks-off phase. On the other hand, the ankle joint dorsiflexed gradually as the motion started, and began to

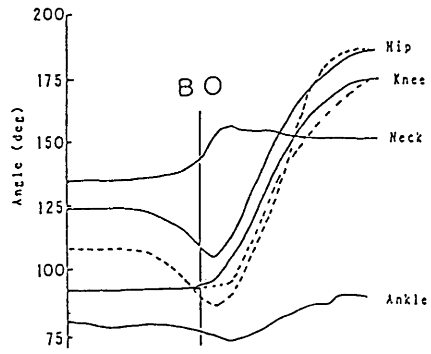

Figure 7. Joint angle at the hip and ankle in the ordinary rising motion (continous line) and in the rising motion with increased trunk flexion (broken line of the hip and knee)

plantar-flex after buttocks-off phase. And then it reached the neutral position at the end. In the ordinary standing-up motion, it was observed immediately after buttocks-off phase

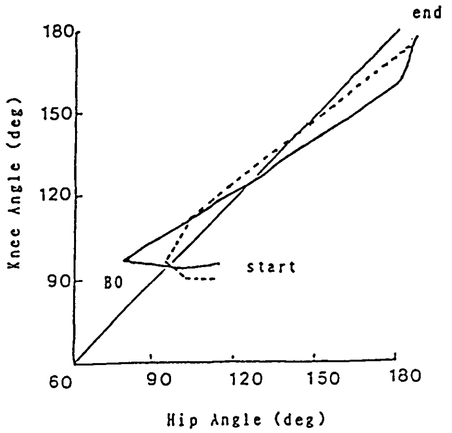

Figure 8. Relationship of hip and knee joint angles in the ordinary rising motion (broken line) and in the rising motion with increased trunk flexion (continuous line)

where knee extension always preceded hip extension. But it was not observed in Condition 2. In Condition 1, the hip and knee extended at almost same proportion, while in Condition 2 the hip extension had a higher proportion than the knee. That is, in the rising motion with increased trunk flexion, the hip-knee relationship was deviated from change in same proportion at the hip and the knee joint (Figure 8).

4) Electromyography

Figure 9 showed typical pattern of electromyogram of six muscles in Condition 1. The first firing was observed in the tibialis anterior muscle. Then the rectus femoris, the vastus medialis, the gluteus maximus, the biceps femoris, and the gastrocnemius fired in succession. The peak voltage of the electromyogram in these six muscles appeared in the same order. This order was also observed in Con-

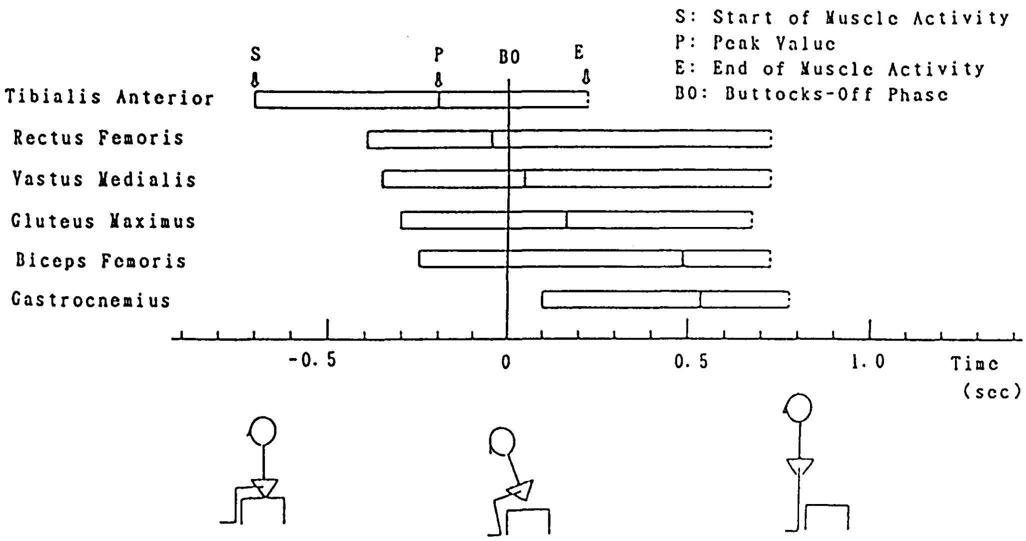

Figure 9. Common firing pattern of the six muscles of the leg

Table 1. Comparison of peak amplitude of surface electromyogram between the ordinary rising and the rising with increased trunk flexion (divided by the value of ordinary rising and expressed as percent)

muscles	ordinary	trunk flexion
Tibialis Anterior	100	75
Rectus Femoris	100	67
Vastus Medialis	100	81
Gluteus Maximus	100	115
Biceps Femoris	100	134

dition 2.

The maximum amplitude of electromyographic discharge in Condition 2 was compared with that in Condition 1. The ratio of the amplitude value to that in Condition 1 was calculated as to each muscle (Table 1). Activity of the rectus femoris and the vastus medialis (knee extensors), and the tibialis anterior decreased, while that of the gluteus maximum and the biceps femoris (hip extensors) increased in the rising motion with increased trunk flexion.

5) Joint moment

Joint moment curves of the hip, knee and ankle were drawn in Figure

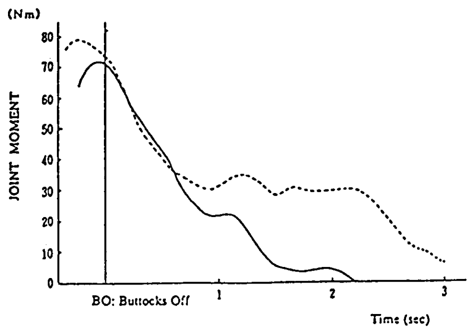

Figure 10. Hip joint moment in the ordinary rising motion (continuous line) and in the rising motion with increased trunk flexion (broken line)

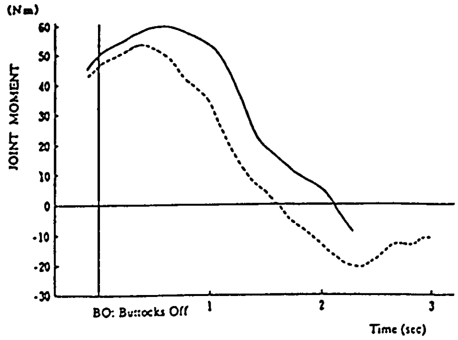

Figure 11. Knee joint moment in the ordinary rising motion (continuous line) and in the rising motion with trunk forebending increased (broken line)

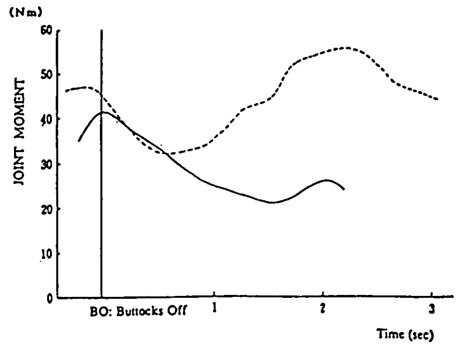

Figure 12. Ankle joint moment in the ordinary rising motion (continuous line) and in the rising motion with increased trunk flexion (broken line)

10 through 12. In the rising motion with increased trunk flexion, the hip joint moment showed larger except buttocks-off phase than that in the ordinary standing-up motion. The difference of hip joint moment values tended to be larger after the buttocks-off. The knee joint moment decreased through all the phases in comparison with the ordinary standing-up motion. Besides, it declined rapidly during the motion and showed minus value at the end of the rising motion. The ankle joint moment was larger than that of the ordinary standing-up, particularly in the later period of the motion.

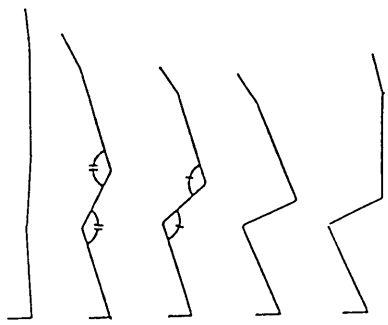

Figure 13. Pantograph-like movement in which the hip and the knee angles charge in same proportion during extending the leg is considered to be a mechanically efficient movement that prevents unnecessary fluctuation of the center of gravity.

DISCUSSION

As seen in the floor reaction force patterns of two types of standing motion (FIgure 5) , the time was prolonged in increased trunk flexion standing. The gradient of force curve to the first peak was less steep. This type of standing can assist the lower extremities in supporting the weight by avoiding rapid weight-loading. Patients with rising motion disorder would feel safety in weigh-loading on the sole by increasing trunk flexion.

The peak vertical component values did not differ statistically between two types of standing. The authors considered that the increased trunk flexion added to the ordinary standing did not affect the vertical component of floor reaction force, although the trunk flexion might increase vertical force a little. The rising motion with increased trunk flexion was not considered disadvantageous. The authors concluded, however, that it was mechanically less efficient since it needed more work for performance of motion than the ordinary type of rising.

The finding that the traced length of the center of pressure showed larger value in increased trunk-flexion rising than ordinary rising indicated that center of gravity of body was shifted more largely. It confirmed inefficiency in the motion.

The relationship between the hip and knee joint angles (Figure 8) is useful to evaluate their coordination. In the ordinary rising the hip and knee extended at almost same proportion, which indicated that the two joints moved like a pantograph (Figure 13). This pantograph movement is considered to make rising motion mechanically efficient and smooth by preventing unnecessary fluctuation of the center of gravity. In increased trunk flexion rising, however, the hip extension had a higher proportion than the knee. That is, the hip-knee relationship was deviated from the pantograph-like movement (same-proportion line or 45-degree line would represent pantograph-like movement in Figure 8). This finding may be another evidence of inefficiency.

The electromyograhic finding demonstrated that no marked difference of firing pattern was found between the ordinary and the increased trunk flexion rising. It was supposed from this result that increased trunk flexion did not exert effect on the motor program of the leg muscles from the central nervous system. Therefore, this way of standing can not be difficult even for the disabled, unless the central nervous system is severely damaged. One of the reason is indicated why this way of standing is commonly recommended for patients with rising difficulty in clinical settings.

It is of importance that joint moment is determined by the center of pressure as well as by floor reaction force. From the viewpoint of joint moment, the increased trunk flexion facilitated forward shift of the center of gravity (the smaller valus of the knee moment in Figure 10 was analyzed as anterior shifting of the center of pressure, since peak vertical floor reaction force showed no difference between two types of rising). This finding expresses an advantage of this type of rising. As shown in Figure 11, however, the more flexed trunk would increase the hip joint moment and would give a burden to the hip extension movement. These finding coincided with the electromyographic observation of muscle activity between the two conditions (Table 1). The authors concluded that the rising motion with increased trunk flexion could give assistance to weakened knee extensors and the tibialis anterior, but that it would burden the hip extensors.

The way of rising with increased trunk flexion has the effect to assist anterior shift of the center of gravity, to decrease the knee joint moment as the knee extends, and to diminish activities of the knee extensors (the quadriceps femoris muscle). This way of standing is considered to be useful as training means for the patients with rising difficulty. However, the way should not be considered the aim of functional training, because it is generally a mechanically inefficient motion. This standing way increases the hip joint moment and activties of the hip extensors. The rising motion with increaesd trunk flexion is considered to be a mechanically disavantageous motion from the viewpoint of kinetic, kinematic and electromyographic findings.

In functional training of rising motion with increased trunk flexion, physical and occupational therapists should be aware of the aforementioned advantages and disadvantages and instruct the patients not to habituate themselves to rise with the trunk flexed largely.

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