Research Paper Review

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How do elliptical machines differ from walking: A study of torso motion and muscle activity

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ABSTRACT

Background

The elliptical trainer is a popular exercise modality, yet its effect on the lumbar spine is poorly understood. The purpose of this study was to analyze the effect of different hand positions, speed and stride lengths on spine kinematics and corresponding muscle activity while using the elliptical trainer, and compare with those demonstrated in normal walking.

Methods

Electromyographic data was collected over 16 trunk and gluteal muscle sites on 40 healthy males (mean age (SD)=23(3)) while on the elliptical trainer. Two stride lengths (46, 66cm), 2 speeds (self-selected, 30% faster), and 3 hand positions (freehand, central bar, handles) were analyzed. Lumbar spine kinematics was calculated from data collected using a motion capture system. Results were compared to those found in walking using repeated measures ANOVA for each dependent variable with Bonferroni adjustments ($P<0.004$. Correlations were made between lumbar motion and various anthropometric measures.

Findings

All significance levels comparing walking to elliptical varied according to stride length, speed and hand position. Average lumbar flexion angles and lumbar rotation were generally greater on the elliptical trainer, whereas walking produced more frontal motion. Total lumbar flexion/extension was similar between the two activities. Muscle activation patterns of the gluteal muscles were consistently higher on the elliptical, whereas the back extensors, latissimi and internal obliques were greater in only selected conditions.

Interpretation

The various hand positions, speeds and stride lengths affect lumbar motion and muscle activity on the elliptical trainer, thus must be considered when incorporated into an exercise protocol.

ANALYSIS

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Background Information

Often, individuals interested in performing cardiovascular exercise use the elliptical trainer as an alternative to treadmill running or stationary cycling because of its low impact requirement. Studies have shown that elliptical training has a similar metabolic cost to treadmill running, making it a reasonable exercise alternative (1). However, the kinematics involved in elliptical use have not yet been studied fully. Understanding the kinematics behind using the machine is important, as many individuals find that its use provokes low back pain, while many claim no ill effects and enjoy this form of exercise. Additionally, the fact that most elliptical machines allow for different hand positions, stride lengths and speeds adds even more variability in this already unclear picture of the potential mechanism of injury in the lumbar spine.

To date, no literature has examined the effect that elliptical training has on lumbar spinal kinematics and muscle activation patterns. Therefore, the authors of this study sought to understand how different hand positions, speed and stride lengths effect spinal kinematics, and how these variables impact muscle activation patterns compared to similar values observed during normal walking.

PERTINENT RESULTS

- Spinal motion while exercising on the elliptical trainer is not the same as kinematic motion of the spine while walking.
- All hand positions and stride lengths used on the elliptical trainer resulted in an increased average forward flexion lumbar spinal posture compared to walking.
- Total sagittal motion (i.e. total flexion/extension ROM during the activity) was similar to that of walking.
- Total rotation about the vertical axis of the lumbar spine (i.e. transverse plane motion) was greater in all elliptical conditions compared to walking, except for the 46 cpm, holding on to the central bars, while pedaling at a normal speed (46 cpm/bars/normal).
- Only frontal plane motion was greater during walking, compared to all elliptical conditions, save both 66rpm/freehand conditions.
- Correlational analysis discovered that posture and kinematics during walking (i.e. rotation, flexion/extension and forward lean) are moderately predictive of similar motions while training on the elliptical. Only frontal motion was poorly predictive.
- When subjects pedaled at a faster rate, this led to greater flexion/extension and rotation movements, and higher than average angles of lumbar flexion. However, higher speeds resulted in no significant change in lateral bend.
- Increasing one's stride length resulted in greater motion about all 3 measured spinal axes, but did not result in an increase in average flexion angle.
- Total flexion/extension and lumbar rotation were highest while holding onto the handles and lowest while holding onto the bars, while freehand elliptical training resulted in the greatest amount of

lateral bending. Holding the handles resulted in the least amount of lateral bending.
- Generally, taller and longer-legged subjects utilized less rotation, but assumed a greater average flexion angle.
- A lack of hip extension (measured in only one patient) could result in greater lumbar rotation motion (keep this in mind for the elderly folks with hip arthritis that you may be training or counseling) – this concept requires further study.
- Peak trunk muscle activation was greater on the elliptical. Significance varied with different speeds, hand positions and stride lengths. The greatest amount of gluteal activation occurred in the 66 cpm/freehand/ fast condition.

CLINICAL APPLICATION & CONCLUSIONS

Exercising on an elliptical trainer generally results in greater lumbar rotation and forward flexion angles, and less lumbar lateral bend compared to walking. This is significant, as repetitive flexion and axial rotation are causative factors in lumbar spine degeneration, annular delamination and disc herniation. Thus, because of this association, using the elliptical trainer may be problematic for those who are intolerant to repetitive flexion/rotation (i.e. patients with discogenic disorders).

Hand position, velocity and stride lengths have significant effects on spinal mechanics. Those with flexion intolerance should perhaps avoid holding onto the central bar for support, as in many individuals, it encourages a more stooped, flexed posture. Holding onto the central bar also results in the least amount of lumbar twist, which may be advantageous to some. Pedaling with greater speed and greater stride length often produce the largest amount of spinal rotation and sagittal motion, and should be used with caution.

Additionally, taller people should use the elliptical with caution, as being taller and longer-legged could encourage greater flexion depending on the orientation of the machine. Shorter people often stand more upright but rotate more. This kinematic data should be kept in mind when prescribing cardiovascular exercise to patients of a certain size and having specific movement intolerances. Also, limited hip mobility can result in greater spinal rotation and flexion to compensate for the lack of hip mobility. This is important, as many individuals with limited hip mobility often present to our clinics with low back pain. Despite of all this, exercising on the elliptical trainer is an excellent tool for encouraging glute activity.

Recommendations about using the elliptical trainer should be made on a case-by-case basis; no absolute statement regarding its effect on the low back can be made, as individuals of different shapes and sizes, and different usage techniques result in different spinal kinematics.

STUDY METHODS

40 healthy males between the ages of 19-35 were recruited from a university population. Participants were free of acute/chronic low back pain, hip pain, or any other injury which could potentially interfere with participation.

Height, weight, arm length and leg length were measured in all subjects. Surface EMG signals were collected bilaterally from the rectus abdominus (RA), external oblique (EO), internal oblique (IO), latissimus dorsi (LD), erector spinae at T9 (T9ES) and L4 (L4ES), gluteus maximus (Gmax) and

gluteus medius (Gmed). Maximal voluntary contraction EMG signals of each muscle were measured for normalization purposes. EMG values were captured during each elliptical and walking trial.

Eight infrared cameras were used for motion capture. Reflective markers were placed on each subject's shin, thigh, foot, hand, forearm, at the midline of the posterior pelvis, T12 and forehead.

Hip extension was measured in the Modified Thomas Test position using a custom goniometer specially designed with a blood pressure cuff under the lumbar spine. This allowed the researchers to know when pure hip extension ended and lumbolsacral extension due to soft tissue drag began.

Motion capture was performed while each subject walked at a comfortable pace. Cadences while walking ranged from 41-60 gait cycles per minute (cpm) and stride lengths between 56-90 cm. Subsequent to this, subjects were asked to begin exercising on the elliptical machine at a self-selected speed for 30 minutes. They were encouraged to try all 3 hand positions: holding the moving handles, holding the central stationary bar and freehand. Stride lengths on the elliptical varied from 46-66 cm. Lumbar spine kinematics were measured using Visual 3D software.

STUDY STRENGTHS / WEAKNESSES

Strengths

- This is the first study to examine the effect of size, speed and hand position while using the elliptical.

Weaknesses

- The study was limited to a small number of fit, younger males (no female subjects).
- In the subjects included, arthritic changes are unlikely to be present – therefore further studies should include older subjects.
- Only one model of elliptical trainer was used.
- Only one person with limited hip mobility was included in this study, and thus no absolute correlation between hip mobility (or lack thereof) and spinal kinematics can be made.

Additional References

1. Mier CM, Feito Y. Metabolic cost of stride rate, resistance, and combined use of arms and legs on the elliptical trainer. Res Q Exerc Sport 2006; 77: 507–513.