LIFTING TASK: PARAMETERS VARIATION ON STABLE AND UNSTABLE SURFACE

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Abstract: Low back pain is complex and costly to society and the development of treatment options. LBP is caused by up to 97% of cases by alterations mechanics of the spine, mostly unspecific disorders is muscle-ligamentous origin and other less common source degenerative or age-related, such as herniated discs (4%) or spinal canal stenosis (3%) \cite{1}. Only 1% of cases are attributable to non-mechanical causes, such as malignancy or infection, visceral alterations (renal, pelvic organs, gastrointestinal) that produce referred pain. Several studies demonstrated greater trunk activation when comparing similar exercises performed on an unstable surface versus a stable base, the spine may become unstable because of weak trunk-stabilizer muscles, and a lack of back-muscle endurance is strongly associated with LBP. This study was to investigate the biomechanical characteristics (kinematics and kinetics) of a lifting task situation on stable and unstable surfaces and postural responses during lifting on stable and unstable situations.

Practitioner Summary: The aim of this study was to investigate the biomechanical characteristics (kinematic and kinetic) of lifting loads in stable and unstable surfaces. this is a task with a strong presence in the recent changes in work, however no systematic studies have been conducted on the effects and consequences of lifting loads on unstable surfaces. This study contributes to understanding the difficulties associated with this task, as well as the biomechanics and ergonomic requirements to consider.

Keywords: Kinematics, kinetics, Load Lifting, Spinal stability, Ergonomics

1. Introduction

In research the task of lifting loads, previous studies found some differences in the kinetics of squatting position in resistance training. Significant differences were found at the peak of the concentric phase; strength, power and speed, similar results were found in the eccentric peak power.

Differences were observed mainly in the transition from stable to unstable surface. In addition, other studies have shown increased activation of the trunk to compare similar exercises on an unstable surface against a stable base. In these cases the spine may become unstable due to the weakness of the stabilizing muscles of the trunk and a lack of strength of the muscles of the back, which is strongly associated with low back pain.

The stability of the column has been described as the capacity of the column for limiting movement patterns, this is used to prevent damage and also to limit the irradiation to the structures of the spine and spinal cord \cite{7} Responses muscles of the legs and trunk to the sudden discharge of the arms and hands has implications for the balance and stability of the spine. Although many authors differ on this concept, instability is considered an overall increase in movements associated with back pain and nerve root. Pope and Panjabi defined instability a loss of rigidity of the column, which produces abnormal movements and increased movement in the segments; to movement, instability may be abnormal in quality (abnormal coupling patterns) and the amount (increased movement) \cite{5}. Balderston, defined segmental instability as: "A loss of rigidity of the core, so that the application of force to that segment produces a greater displacement than is normal in structure, resulting in a painful condition, with potential progressive deformity and neurological structures are at risk \cite{6}. Commissaris and Toussaint, in lifting loads, saw an 8% increase in loss of balance when comparing squat and stoop variants (loss of 36% of the balance is due to the change of posture, increased trunk flexion), also have reported the benefits of a better balance in the upper body, which can
reduce the cost of stooping; physiological elevation also suggest that the preservation of balance in lifting an unstable load is harder than lifting in a stable load.

The aim of this study was to investigate the biomechanical characteristics (kinematic and kinetic) of lifting loads in stable and unstable surfaces. 1) Duration of lifting the load, 2) time relative phase, and 3) the angular displacement (velocity and acceleration); the postural responses during the uprising in stable and unstable situations, the kinematic variables as studied joint angles (trunk, pelvis, hip and knee) and kinetic variables and 4) velocity of the center of pressure (CoP) 5) Area CoP (relative to the base of support (BoS)).

The hypothesis of this study are that the differences in these variables can be found between different situations: the duration of lifting will increase with increasing instability; time phase increase in the upswing; the angular displacement of the trunk, pelvis, hip and knee, vary due to instability, less speed and low accelerations; CoP velocity increased or decreased displacement (x- projection) in relation to the lateral, anterior, posterior; CoP area the increase relative to the support base (BOS) surface in each situation.

1.1 Methods and materials

Subjects: 4 volunteers (2 men and 2 women) students, completed the informed consent, medical history, and evaluations with required inclusion criteria and previous explanation for the research. Were excluded if they had a history of back pain experienced low back injury in the past 6 months, or if they had a chronic disease that may have affected its capacity, surgeries or traumatic events in the lumbar spine.

Experimental Protocol: For the start, the volunteers responded to the health history and the Nordic test. We provide a brief explanation of the technique (to phases differs) of lifting and positioning platforms laboratory analysis. No restrictions to the lifting technique were required, that means that the subjects could choose the technique they wanted. However, if the subjects took a step, the trial was excluded from the analyses. The load lifting will be done from the ground to the bipedal position, with the load placed on the median plane of the upper limbs with the trunk, the load return to the initial position, with the indication of the expert. The different conditions in which subjects were perform the lift:

* First on the floor without any variation of the height
* Second: surface in the movement must be performed is (49.5 x 49.5 x 10 cm).
* Third: surface is a little unstable with the following characteristics (39.5 x 40 x 9 cm)

The characteristics of the load to be handled for the execution of the lift is a box (36 x 36 x 25 cm) the grip has side grips for providing grip full hand and avoid awkward postures and external rotation, shoulder abduction and flexion, should facilitate grasping and accommodating load close to the trunk to avoid awkward postures and head, neck and spine. The recommended dimensions are length not exceeding 40 cm shoulder, recommended width 35 cm. Inside the box weight is suitable for men 11 kg and women 6 kg, specifically.

Definition of Task Phases: The subjects in the first phase should be in the anatomical position bipedal, given the signal to begin the second period of down, must make a flexion trunk and lower limbs, (each choose the style), for lifting the charge from floor, using the side grip handles and the movement end, maintain the load in the bipedal position, the phase "stop". Each subject of these steps must be performed on all three surfaces (normal or ground, small and large), which vary instability each challenge trial should be to maintain the balance under surface. (Any compensatory movement observed during the execution of the technique must be stopped and started again with the order of the laboratory specialist.).

Data: Since the data was not normally distributed, non-parametric tests were used, and median, min/max and range was used to describe the distribution. To test potential differences between the different stability conditions, for all variables a median test was used. If the p-value was lower than 0.1, the Mann-Whitney U-test was used as a post-hoc test to detect between which the situations the differences were situated. For all statistical analyses, SPPS Statistics®, version 20.0 for Windows 7 Microsoft Inc®, was used (SPSS Inc., Chicago, IL, USA).

2. Results

1. Phases: The median total time for the three phases was 1, 90 for situation A, 1, 75 for B and 1, 69 for C (Table 1). There was no significant difference between the three situations. For the downward phase expressed as percentage of total movement time, there was a tendency (p=0.063) that the stable situation was longer than the instable situations (Table 2). In the percentage total time in upward the instable situation B showed more difference significantly in relationship whit others.
Table 1. Results of down and upward phase and relationship with total time (sec). Percentage Total Time in once each phase. The Differences between the surface (A) stable, (B) big instable surface and (C) small surface instable represented in the values the median min and max.

<table>
<thead>
<tr>
<th></th>
<th>TOTAL TIME (SEC)</th>
<th>DOWNWARD PHASE (% TOTAL TIME)</th>
<th>UPWARD PHASE (% TOTAL TIME)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median A</td>
<td>1,9</td>
<td>56</td>
<td>43,2</td>
</tr>
<tr>
<td>Minimum A</td>
<td>1,0</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Maximum A</td>
<td>2,4</td>
<td>70</td>
<td>85</td>
</tr>
<tr>
<td>Median B</td>
<td>1,75</td>
<td>52,8</td>
<td>47</td>
</tr>
<tr>
<td>Minimum B</td>
<td>1,0</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Maximum B</td>
<td>2,2</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Median C</td>
<td>1,69</td>
<td>58,3</td>
<td>42</td>
</tr>
<tr>
<td>Minimum C</td>
<td>1,0</td>
<td>10,4</td>
<td>24,5</td>
</tr>
<tr>
<td>Maximum C</td>
<td>2,7</td>
<td>75,5</td>
<td>89,6</td>
</tr>
</tbody>
</table>

Figure 1. Boxplot (left) presented the percentage the down ward phase and the percentage the upward phase (right) where the three situations (A, B and C) in relationship with the total time showed differ significant during lifting. The percentage in the total time (see graphic left) presents minimal variability of the median, the distribution is not symmetrical in any of the cases of the surface, but in the trial (B), showed higher amplitude values between 58 and 15 sample. The percentage in the total time the up phase (see graphic right), not represented differences significantly.
2.2 Kinematics

Table 2. The angles description for: the trunk, hip, pelvis, knee and foot for the down and upward relationship with each phase. Represented in the values the median min and max

<table>
<thead>
<tr>
<th></th>
<th>TRUNK DOWN</th>
<th>TRUNK UP</th>
<th>HIP DOWN</th>
<th>HIP UP</th>
<th>PELVIS DOWN</th>
<th>PELVIS UP</th>
<th>KNEE DOWN</th>
<th>KNEE UP</th>
<th>FOOT DOWN</th>
<th>FOOT UP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>41,525</td>
<td>35,025</td>
<td>63,350</td>
<td>60,150</td>
<td>13,700</td>
<td>7,750</td>
<td>81,775</td>
<td>76,700</td>
<td>16,575</td>
<td>19,775</td>
</tr>
<tr>
<td>Minimum</td>
<td>25,3</td>
<td>3,1</td>
<td>36,1</td>
<td>9,1</td>
<td>3,9</td>
<td>2,0</td>
<td>47,0</td>
<td>37,8</td>
<td>5,5</td>
<td>10,8</td>
</tr>
<tr>
<td>Maximum</td>
<td>69,5</td>
<td>57,6</td>
<td>108,3</td>
<td>83,1</td>
<td>25,0</td>
<td>24,1</td>
<td>97,1</td>
<td>106,2</td>
<td>32,1</td>
<td>25,2</td>
</tr>
</tbody>
</table>

Figure 2 showed that Hip Left angle range during the downward phase tended to be larger (p=0.096) in the stable condition (md=64.55), compared to the instable condition C (md=47, 55). There were no differences between conditions A and B (md=58, 65), and no differences between B and C using the post-hoc tests.

Figure 3 Boxplot angle hip range down left presented the Median (bold line), min and max values expressed by horizontal lines, while the boxes represent 25%-75% percentiles in each condition A-B and C.
For the foot right angles maximum during the downward phase showed the tendency (p=0.097) that the stable condition (md=67, 2) was larger compared to instable condition C (md=63, 7), and the unstable condition B (md= 67, 2) was larger than C. But the condition A and B not differed significantly. For the foot left angles range the downward phase (p=0,050) wit the median test. In the stable condition (md=69, 2), was longer compared to instable condition C (md=64, 4) and unstable condition B (md=65, 9) was larger than condition C. Not there differed significantly that condition A and B.

Foot angle max down right (left) and Foot angle max down left (right) (n=4) subjects, in relationship whit the conditions (A-B-and C), the median is not in the center of the rectangle. The distribution is not symmetric with a few variances. For the foot right range angles during the downward phase, showed the tendency (p=0,097) that the stable condition (md=21, 7) was larger compared to instable condition C (md=21, 4), and the unstable condition B (md= 21.4) was larger than C. But the condition A and B not differed significantly. For the foot left angles range the downward phase (p=0,368) whit the median test. In the stable condition (md=18, 9), was longer compared to instable condition C (md=14, 7) and unstable condition B (md=20, 5) was larger than condition C. Not there differed significantly that condition A and B. Foot angle range up right (left) and Foot angle range up left (right) (n=4) subjects, in relationship whit the conditions (A-B-and C), the median is not in the center of the rectangle, the distribution is not symmetric with a few variances.

2.2.1 Angular Velocity

The median trunk right max velocity in the downward phase (see figure xxx Right) was (md=96, 4) degrees/sec in the stable situation and this was to be higher (p-value = 0.717) than the instable B (md=87.5). The instable situation C (md=96,7), equals a stable condition or not showed variances significant, (see figure xx). For the upward phase there were no differences. The trunk angle left max in the downward phase showed tendency (p=0,089) the median in the instable condition B (md=87,4) was slower than stable (md=96,1). Not showed many variances with the condition C.

Trunk velocity max down in left (left) and Trunk velocity max down in right (right) for 4 subjects, in relationship whit the condition (A-B-C) showed differs significant in the three situations. The median pelvic angle MAX velocity in the downward phase (Right) was (md=43.5) degrees/sec in the instable situation B and this was to be slower (p-value = 0.039) than the stable (md=67, 5) and the instable situation C (md=64) (see figure). There was no difference between the conditions A and C. For the upward phase there was no difference. The pelvic velocity max down in Right in relationship whit the condition (A-B-C) showed differs significant in the three situations the distribution is not symmetric with a few variances.

The pelvic velocity range in the downward phase tended to use a larger range (p = 0.039) during the stable condition (md 129) compared to condition C (md 94, 8) during down phase. There were differences between condition A and B, with the (md=87, 4) slower than stable situation. The condition C was similar with B. For the upward phase and left side there was no differences. The pelvic velocity range in the downward phase in relationship whit the condition (A-B-C) showed differs significant in the three situations the distribution is not symmetric with a few variances.

Foot velocity max during phase down showed a tendency (p=0,022) where showed (md=38,4) for the instable condition C in between whit the condition A (md= 11, 7) were higher than condition stable. In the condition B (md= 23) were higher than condition A. Not there differed significantly that condition C and B. Foot velocity left max down showed the range in relationship whit the condition (A-B-C) for identification variances.

2.2.2 Kinetics

The CoP Anterior/Posterior range per upward stable condition A (md= 88, 7) showed changes significantly during lifting displacement to vertical projection was major in comparison unstable condition C (md=61, 07), in the upward phase. So the differ between condition A and B and C no was significantly, on AP/-range during the upward phase expressed in mm. No significant difference between A-B and B-C conditions The Anterior and Posterior max downward not showed variances significant between A whit the (md= 323-B or C condition, on AP/-range during the upward phase expressed in mm. No significant difference between A-B and B-C conditions
3. Discussion

The relative phase time showed more time in instable C for two phase down (md=58,3) and up (md=89,6), this could show that at the time of variation the unstable surface anticipatory response in muscular component and speed of response over time is longer, then, if the answer in lifting and back to the anatomical position are higher in comparison to the surfaces A and B.

The references to the angular displacement in the segments with significant differences are angles in range Hip left during downward phase, the major values strategy for stable A is differ for instable C, because, in the instable surface C, the strategy not is specific the increase angle hip joint, should use other response system. In this case in instable surface the angles hip joint is less, thereby, it is need more stability without increasing the angles. Spinal instability has been investigated as a risk factor for LBP and injury, providing appropriate ergonomic suggestions based on the biomechanics can improve the tolerance to work in different surfaces.

Acknowledgements


References


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