TRUNK AND HIP ANALYSIS DURING GAIT IN POST-DISCETOMY, ACTIVE LUMBAR STABILIZATION

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TRUNK AND HIP ANALYSIS DURING GAIT IN POST-DISCETOMY ACTIVE LUMBAR STABILIZATION (Abstract): This paper presents a post-discetomy rehabilitation program through active lumbar stabilization with focus on trunk and hip movement analysis during gait. Material and methods: Analysis consisted of a kinematic gait study, with kinematic point tracking and software data processing in MATLAB. The analysis was performed on a patient with L5-S1 discectomy. The purpose was to track progress and change in trunk and hip during the rehabilitation program and to establish a relationship between trunk and hip movement during gait, in regards to the patient’s rehabilitation program. Results: Trunk and hip analysis during gait showed significant differences in patient hip and trunk rotational movement between the three analyzed readings of the patients. Changes were found in both left and right hip flexion-extension coupling and flexion in terminal swing. The rotational movement of the trunk is reduced in a more physiological margin from -13.4 to -1.0 anterior-posterior movement which correlates with un improved in transversal rotation. The analysis made for hip and trunk synchronization revealed an increased synchronization after the end of the functional reeducation program. Conclusions: This method allowed to evaluate changes in trunk and hip motion during gait. Tracking and visualizing the motion between trunk and hip during gait gives a better understanding of the importance of each movement and the strong link between gait phase coordination and motion angle amplitude. It gives a new perspective on the rehabilitation process that targets lumbar stabilization. Keywords: REHABILITATION, GAIT ANALYSIS, DISK HERNIATION.

Lumbar discectomy is one of the most common surgical treatment in lumbar disc herniation. The main goal of the postoperative rehabilitation program is to restore lower spine movement and strength of the corresponding muscles.

To our knowledge, trunk and hip kinematic data during gait has not been yet clearly defined. There is a general understanding on flexion, extension, rotational movements and synchronous phenomena that occur between trunk and hip during gait. There are few studies (1, 2,3) that describe a kinematic analysis of the relationship between trunk movement and hip/pelvis movement during gait. In a kin-
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ematic study (3), overlapping trunk and hip curves results in a common area. This common area describes the time frame where trunk and hip, align. Shape, size and other detail aspects of the area are important to determine imbalanced movements and muscle realignment need. Also, the trunk and hip coordination in gait phases is important as de-synchronization affects gait performance as well as pathological kinematic angles (4). It is important to note that this type of analysis does not have a scientific study reference yet, but has the foundation of what is already known in terms of trunk and hip kinematics.

During the rehabilitation program, the physiotherapy specialist follows an already established protocol, making some changes to accommodate the patient’s current state and health history.

Lack of objective feedback in a rehabilitation physiotherapy type program is an issue. Pain scales such as Visual Analog Scale (VAS), movement tests such as Prone Instability Test, Passive Lumbar Extension Test and Lumbar Dynamometry are current evaluation test that quantify the progress of a rehabilitation program.

**MATERIALS AND METHOD**

The study was conducted in the Physio-kinesiotherapy and Rehabilitation Center of “Grigore T. Popa” University of Medicine and Pharmacy Iasi.

The patient studied was a 37 years old male, of height 1.8 m and of weight 70 kg. He came to the center for rehabilitation after having a lumbar discectomy surgery at L5-S1 level 4 weeks prior. The rehabilitation protocol for our patient consisted of a four-stage program of active lumbar stabilization(ALS) exercises (5). The four stages are muscle re-education, static stabilization, dynamic stabilization and functional activities. In total, for our patient, the rehabilitation program consisted of 30 sessions set throughout a period of 4 weeks.

Gait analysis was performed 3 times. First evaluation was made at the start of the rehabilitation program to assess the initial patient’s gait and will be referred to as A1 in the study. The second time was after 15 sessions, referred to as A2, and the third time at the end of the rehabilitation program referred to as A3.

To perform the gait analysis, the patient was asked to walk at a normal walking speed rate covering a distance of 10 m, back and forth for 10 times. Body landmarks were established for trunk, pelvis, hip, and knee. Four digital cameras were positioned to record from the front, back, left and right. Video analysis was performed using DLTdv3 digitizing toolbox for MATLAB® (6) to track the landmarks. General functions in MATLAB® where used to obtain gait angles for each gait segment, plotting values and data comparison. We used MATLAB® version R2007b with license number 336.240.

Values were obtained for speed, step length, duration of gait phases and motion angles at each gait segment. The angles were plotted to obtain kinematic gait graphs.

Regarding these kinematic gait graphs, the overlapping area mentioned earlier occurs during gait between the Terminal Stance and Initial Swing phases (3). During gait, this is the interval where the pelvis/hip and the trunk align. In normal gait and at normal walking speed the trunk rotates counter clockwise with forward leg movement, all while the pelvis and hip rotate in the opposite direction. The coor-
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dination of trunk and hip movement is important for an optimal and efficient gait. By analyzing these areas, our focus was to find a relationship between trunk and hip kinematics with respect to gait phases and follow progress throughout the rehabilitation process. This was also a method of quantifying the link between trunk and hip movement during gait.

RESULTS AND DISCUSSION

For a better understanding of our patient’s trunk and hip movement coordination during gait we first made a general analysis of hip kinematics in sagittal plane. In figure 1 are plotted the left hip angles during gait for each of the three-gait analysis made. Of interest to the study was the Pre-swing phase timing during gait and differences in angle amplitudes.

The red line corresponds to A1, before rehabilitation started, the light blue line corresponds to A2 and the dark blue line corresponds to A3. There is a considerable difference in the graphs showing a clear change of patient’s gait at hip level (fig. 1).

![Fig. 1. Comparison between first, second and third gait analysis of hip movement angles in sagittal plane (left side)](image)

At initial contact in A1 the hip flexion was 15°, half the value of the average normal (7). During terminal stance, the hip reaches a maximum of 13° of extension and then continues with a flexion of approximately 19° during mid-swing, ending the cycle with a decrease in flexion to 18° in terminal swing. The values found are significantly lower than the normal averages (7) and describe a deficit in movement amplitudes during gait, both in flexion and extension of the hip. In A2 flexion at initial contact increases to 16°, extension decreases at 9° in pre-swing and flexion increases at 23° in terminal swing. At this stage, values get closer to normal range except for extension in pre-swing. In A3, flexion at initial contact increases to 18°, extension increases at 15° in pre-swing and flexion remains at 23° in terminal swing. A3 exhibits values that are in normal range (7). This shows a clear progress and a good rehabilitation of our patient.

In figure 2 the dotted lines correspond to the right hip for each of the analyses and have corresponding colors to the ones from the left side. The graphs for the right side are reversed so that they match the left side.
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for a better comparison. This comparison was made to illustrate if there were any differences in values or coordination of gait phases between left and right hip.

In A1 there is a difference in pre-swing phase timing between left and right (marked with red arrows). This desynchronization is also present in A2 but the difference between the phase timing is smaller than in A1 (phase timing is marked with light blue arrows).

In A3 there is a clear synchronization between left and right (marked with dark blue arrows). This shows that left and right hip match in phase timing and have very similar motion amplitudes. To get more into detail, in pre-swing, when the pelvis drops it is stabilized by a complex set of muscles (rectus abdominals, external oblique, iliopsoas, low back extensors, hip extensors and hip flexors). If these muscles from one side do not work in synch with the ones from the opposite side than it translates on the graph in a difference in amplitude and timing of gait phase.

In figure 3 are plotted the left trunk angles in sagittal plane during gait for each of the three-gait analysis made. For an easy reference, we kept the colors corresponding the each of the gait analysis.

![Fig. 2. Comparison between first, second and third gait analysis of hip movement angles in sagittal plane (left and right side)](image)

![Fig. 3. Comparison between first, second and third gait analysis of trunk movement angles in sagittal plane (left side)](image)
In A1, trunk remains in a constant hyper-extension with values varying with gait phases. The trunk oscillates in sagittal plane with values ranging in the interval of (-13, -4). At initial contact trunk is extended at -13°, which is more than double the average normal value (8).

In A2 there is still a predominance of hyper-extension of the trunk but not as fluctuating in amplitude as before rehabilitation started.

However, in A3 trunk extension is significantly reduced. The arrows in the right in corresponding colors show the amplitude interval for trunk in each gait analysis. In A3 the trunk oscillates in sagittal plane with approximate values ranging in the interval of (-10, 0). Compared to A1, at initial contact in A3, trunk is extended at approximately 7°.

In fig. 4 the dotted lines correspond to the right trunk for each of the analyses and have corresponding colors to the ones from the left side. The graphs for the right side are reversed so that they match the left side for a better comparison. A1 and A2 do not have symmetrical left versus right trunk graphs. There is also a difference in flexion moment in A1 where peak areas do not overlap. A3 shows a similarity between left and right curve with a slight bigger value of flexion on the right side.

![Fig. 4. Comparison between first, second and third gait analysis of trunk movement angles in sagittal plane (left and right side)](image1)

![Fig. 5. Overlapping area comparison between trunk and hip movement angles in first, second and third gait analysis (left side)](image2)
In figure 5 are highlighted the overlapping areas between hip and trunk gait graphs. Each overlapping area has the color corresponding to the graphs from A1, A2 and A3 gait analysis. As explained earlier this marks the time frame where hip/pelvis and trunk align.

Overlapping area in A3 is greatest and is located at the middle of the gait cycle. This translates in a good motion synchronization. Peak of trunk curve is when trunk bends forward to move the center of mass outside the base of support. Lowest point on the hip gait graph is when hip is in maximum extension and prepares for toe off to continue in swing phase. Therefore, an increase in sagittal plane flexion of trunk would raise the curve making the overlapping area bigger. Also, a decrease of hip extension would raise the curve, making the area smaller. Ideally, there must be a balance between motions of segments.

Regarding the position of the overlapping area with respect to the gait curves, the optimum position should be in the middle of both curves. That is because maximum hip extension and trunk flexion should occur at approximately 50% of gait cycle. In A3 overlapping area occurs as normal.

In figure 6 are included the graphs corresponding to hip and trunk from right side and are highlighted the overlapping areas between hip and trunk gait graphs. For a better and clear view, only graphs from A1 and A3 are shown.

![Graph](image)

**Fig. 6.** Overlapping area comparison between trunk and hip movement angles in first and third gait analysis (left and right side)

After the analysis of the kinematics of trunk-hip related rotational movement we can conclude that the transvers rotational movement of the hip and trunk improved. That means that the patient could move with a hire discrepancy between the two segments because of the increased dynamic stability which promoted higher transversal rotational movement.

We found similar results in the only two articles (9, 10) from the scientific literature that covers this subject. The difference is that this studies compared normal versus pathological lower back pain (LBP) patients. They found that the LBP patients compared to healthy people had a more
rigid and less flexible pelvis-thorax coordination.

A significant difference can be seen between the left and right side in A1 overlapping areas. This translates in an overall pronounced and de-synchronized rotation of hip and trunk. Visually, the right-side area is bigger than the left side. In A3, areas are similar in shape and size. This shows a good motion synchronization and amplitude control by muscles that can lead to a decrease in stress forces on lumbar disks.

CONCLUSIONS

Performance and efficiency feedback in rehabilitation program was defined and tracked through a kinematic analysis system. We defined the relationship of trunk and hip motion during gait with respect to the gait phases that allowed for a better understanding of lower back, hip and pelvis muscle action and synchronization during the rehabilitation program. The method allowed for tracking change in trunk and hip motion during gait.

Our method of tracking and visualizing the motion between trunk and hip during gait gives a better understanding of the importance of each movement and the strong link between gait phase coordination and motion angle amplitude. Therefore this also puts a new perspective on the rehabilitation process that targets lumbar, pelvic and hip muscles showing the importance of muscle alignment and synchronization for optimum motion stabilization.

REFERENCES