A study on the Real-Time Biomechanical Analysis of Lumbar Burden Utilizing Stereoscope Cameras

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Abstract

Lumbar region is susceptible to strain and stress due to various physical activities and occupational task. To study about the lumbar burden, researchers have developed many tools but most of existing design can only use static imaging or doesn't provide real-time update. The proposed system records and examines the change of body posture in real time by utilizing the capabilities of stereoscope cameras. By using MediaPipe algorithms, 2D key-points representing body joint can be extracted from images. Afterward, using the Direct Linear Transform (DLT) the corresponding 3D key-points can be calculated using obtained 2D key-points. With the 3D key-points the body angles can be computed and used to calculate the wight of the lumbar burden using JACK calculation. Finally, the proposed system reached to its aim to study about lumbar burden and adjust the person needs in real-time.

Keywords: Lumbar burden, real-time biomechanical analysis, computer vision

1. Introduction

The lumbar region of the spine, commonly referred to as the lower back, is susceptible to strain and stress due to various physical activities and occupational tasks. Around 577.0 million people worldwide, or approx. 7.5% of the total population, were projected to have low back pain at any given time in 2017, and that number is continuing to rise [1]. This incident occurs due to doing the same activities that affect the lumbar region over a long period of time. Examples of activities that cause this include agricultural work, nursing, construction, etc. Therefore, this needs to be monitored and corrected before it gets exaggerated. One of the consequences that can occur due to ignoring pain in the lumbar region is disability [2], [3].

Therefore, many researchers are trying to monitor and improve body movements with various approaches. Among these methods, the approach that is often to be seen is using smartphones and Kinect sensors [4], [5], [6], [7], [8]. The approaches have already taken their respective advantages. However, when it is applied on real scenarios, such approaches demand several additional features. For example, smartphone-based approach, it employs gyro and accelerator sensors embedded on the smartphone to measure changes in body inclination [4]. This change in body inclination will then be used to estimate the lumbar burden that occurs on the body and classify the movements the body makes [5]. On the other hand, the Kinect sensor [6-8] uses a camera to capture human images and a depth sensor to measure the depth of key-points captured by the camera. This data will then be used to obtain 3-dimensional body key points. Afterward, the 3D key-points are being used to estimate the body posture, angles, and the biomechanical of the human body. Each approach has its own advantages and disadvantages. for example, smartphones can be used in all conditions. However, based on the measurement criteria, several devices need to be attached to the body and cannot be monitored in real-time. As for Kinect sensor, the sensor can find out various information on parts of the body at once, but Kinect sensor cannot be used under sunlight.

The proposed system is designed for real-time biomechanical analysis of the body, considering the use in different environmental conditions. This research employs a camera stereoscope to analyze the body and carry out comprehensive calculations in order to identify the lumbar burden in real time.

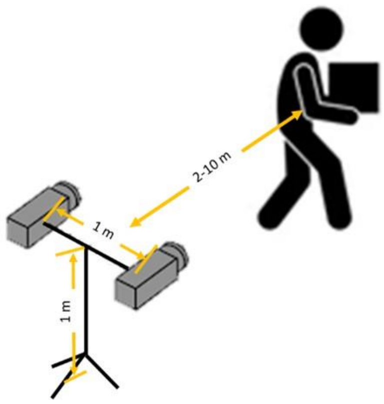

Fig. 1. Camera setup

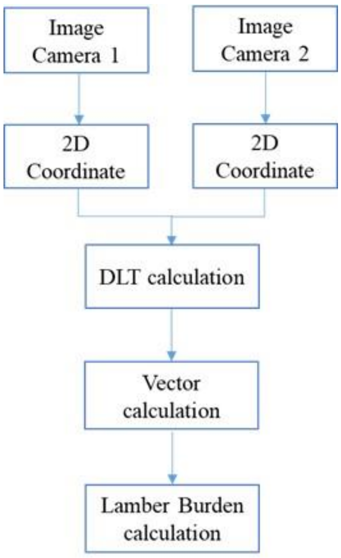

Fig. 2. System Flowchart

2. Methodology

2.1. System setup

The study employed a stereoscope system comprising two cameras to investigate the activities. The cameras were strategically placed on a 1-meter-high camera support with a 1-meter separation, as depicted in Fig. 1. Distance between the two cameras was carefully addressed, as overly close placement could constrain the view, leading to more noise and less precision. Use of stereoscopic approach creates a three-dimensional image, and it leads to a comprehensive understanding of complex movement patterns involved in walking and the factors that influence them. Further, this configuration allows the system to effectively detect movements within a 10-meter range while minimizing noise interference.

2.2. *Data Acquisition*

Data collection is carried out according to the flowchart depicts Fig.2. In order to carry out biomechanical analysis, the system needs to obtain 3D key-points so that monitoring of the desired body parts can be obtained [9]. Initially, the camera captures an image of the subject positioned in front of it. Then the obtained image undergoes processing via the MediaPipe algorithm to extract 2D key-points. Given that the images are derived from two distinct perspectives through two cameras, a pair of key-point perspectives right and left cameras, illustrated in Fig.3. To achieve 3D key-points, some calculations are conducted using DLT method. However, calibration is needed to derive the translation and rotation parameters of the camera in order to carry out DLT calculation. The obtained 3D key-points serve as foundational data for extracting biomechanical insights from the body. Afterwards, in order to compute lumbar burden, it's necessary to deepen the understanding of body posture, one of which is through the body angle. This angle is obtained through vector calculations utilizing the known 3D key-points coordinates. This process involves presenting the 3D key-points within a three-dimensional environment, as visualized in Fig.4.

Fig. 3. 2D key-points from left and right cameras

Fig. 4. 3D key-points

2.3. ***Lumbar burden calculation***

The estimation of lumbar burden involves the computation of body posture angles, as illustrated in Fig.5. Calculations are performed according to formulas Eq. 1, 2, 3, 4, 5, 6.

$$A = (x_1, y_1, z_1) \quad (1)$$

$$B = (x_2, y_2, z_2) \quad (2)$$

$$C = (x_3, y_3, z_3) \quad (3)$$

$$a = (x_a, y_a, z_a) = ((x_1 - x_2), (y_1 - y_2), (z_1 - z_2)) \quad (4)$$

$$b = (x_b, y_b, z_b) = ((x_3 - x_2), (y_3 - y_2), (z_3 - z_2)) \quad (5)$$

$$\theta = \cos^{-1}\left(\frac{(x_a x_b + y_a y_b + z_a z_b)}{(\sqrt{x_a^2 + y_a^2 + z_a^2} \cdot \sqrt{x_b^2 + y_b^2 + z_b^2})}\right) \quad (6)$$

This angle calculation can then be used to carry out biomechanical analysis by applying JACK calculations. The JACK computation demands data on body posture (such as body angle), subject-specific information such as height and weight, and the weight of the object intended for lifting. Fig.6 represents the coordinates involved, and Table 1 provides a detailed description of the corresponding angles denoted by its abbreviations.

In this study, the height of the participated subject was 160 cm with a body weight of 50 kg, with different load settings of objects, ranging from 0 kg (absence of a load) to 2.5 kg and 5 kg. The proposed system records the computed results in an Excel file, facilitating comprehensive post-analysis.

3. Results and Discussion

In order to know the effect of load on lumbar burden, a comparison is needed by providing different loads. In recent research, the load given was divided into 3 loads, namely 0 kg or no load, 2.5 kg load, and 5 kg load. The movement carried out by the subject is the same movement as shown in Fig 7. but the system simulates the target of lifting a different load. The results of the lumbar burden analysis can be seen in the Fig. 8.

Based on the results, it can be observed that the system can analyze the lumbar burden according to the movements made by the subject. Moreover, the load that occurs in the lumbar region is directly proportional with the load that being lifted. The maximum load that occurs in the lumbar region when the subject was at the lowest point and tries to lift the weight; 2098 N for 0 kg, 2843 N for 2.5 kg, and 3612 N for 5 kg (Table 2). Further, minimum, and average values can also be found in Table 2.

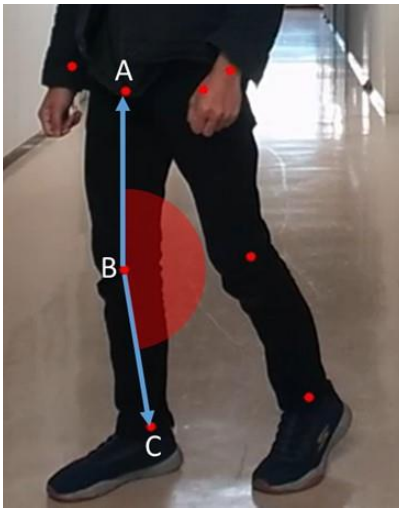

Fig. 5 Vector coordinates

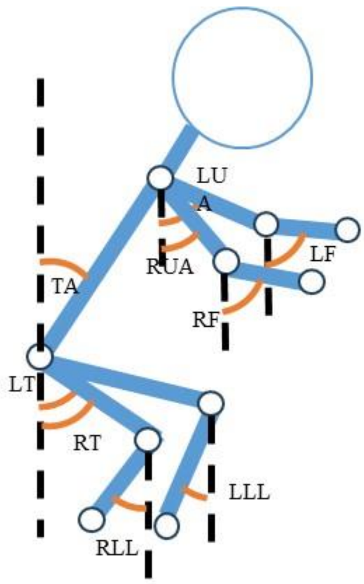

Fig. 6 Respective vector coordinates

Table 1. The coordinate details.

TA	Trunk anteversion angle
RUA	Right upper arm angle
LUA	Left upper arm angle
RF	Right forearm angle
LF	Left forearm angle
RT	Right thigh angle
LT	Left thigh angle
RLL	Right lower leg angle
LLL	Left lower leg angle

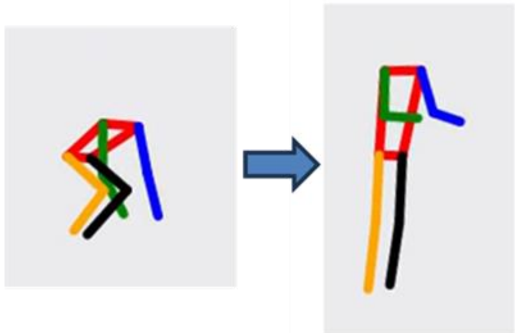

Fig. 7 JACK angle for Lumbar Burden calculation

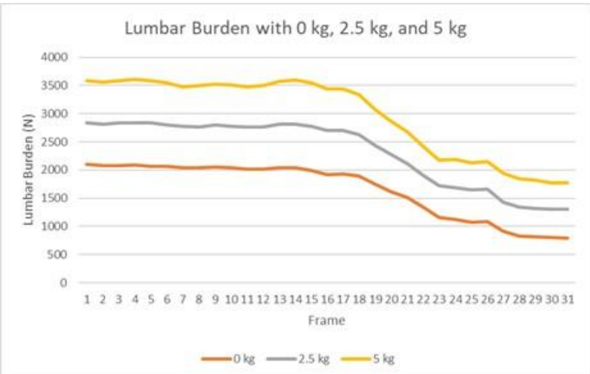

Fig.8. Lumbar burden analysis

Table 2. Lumbar burden Max, Min, and Average

Load (kg)	Lumbar Burden (N)		
	Max	Min	Average
0	2098	790	1655
2.5	2843	1299	2327
5	3612	1770	2974

4. Conclusion

Based on the results it can be concluded that the proposed system can carry out biomechanical analysis to determine the lumbar burden effectively. The procedure was executed in real-time, also enabling monitoring of the system within any occupational settings. Further, the system demonstrated a robust performance under sunlight, showing its adaptability to diverse environmental conditions.

For future work, the observed results will undergo a validation process using an established system to assess the efficacy of the developed system. Furthermore, as a system constraint, the current study is limited to the detection of a single person. Therefore, in order to conduct real-time analysis of lumbar burden for multiple persons, the system requires further development.

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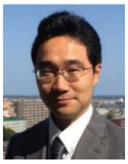

He received the B.E. and M.E. degree from Miyazaki University in 1998 and 2000, respectively. From 2000 to 2001, he was an Engineer in Asahi Kasei Corporation, Japan. In 2001, he joined Toyama University, Toyama, Japan, where he was a Technical Official in the Department of Intellectual Information Systems. In 2006, he joined Miyazaki University, Miyazaki, Japan, where he was an Assistant Professor in the Department of Electrical and Electronic Engineering. Since 2015, he is currently a Professor in the Department of Environmental Robotics. His main research interests are Neural Networks and Optimization Problems. In recent years, he has had interest in Biomedical Signal Processing using Soft Computing.