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Vision Based System for "Free-Weight Back Squat" Angle Assessment

Tharindu Dananjana Silva, B.G.D.A. Madhusanka, H.D.N.S. Priyankara
Department of Mechanical Engineering
The Open University of Sri Lanka, Sri Lanka

Abstract:- This project is focused on analyzes squat performing video through image processing by considering key points taken from front and side view. There are conditions to check the performance of squat correct or not. If the Squat is correct, three angles are analyzed reference to five positions. The OpenCV is used to identify the five positions. Also, the Vector function is used to determine the reference angles by using the Cosine rule. These angles are calculated at the knee, waist, and ankle. All these angles are calculated on the free-weight back squat exercise. The ultimate purpose of this project is to minimize injuries that occur due to technical errors because most of the armature players get injured due to the difficulty in posing of correct technique. The mobile application is developed to identify user mistakes and can get instructions.

Keywords:- *squat, image processing, OpenCV.*

I. INTRODUCTION

Exercise means any bodily activity that enhances or maintains physical fitness and overall health and wellness. It is performed for various reasons. Such as to aid growth and improve strength, preventing ageing, developing muscles and the cardiovascular system, honing athletic skills, weight loss or maintenance, improving health and for enjoyment. Many individuals choose to exercise outdoors where they can congregate in groups, socialize, and enhance well-being. The amount of recommended exercise depends upon the goal and the age of the person in terms of health benefits. Even doing a small amount of exercise is healthier than doing nothing.

Squats have been labelled as the 'king of exercises' by many fitness experts and for good reasons. The Squat is not just a leg exercise since it is a full-body movement where losing additional weight of the body. Squats will predominantly target your quads, gluteus, hamstrings, and lower back muscles [4]. However, core strength & stability, ankle mobility, back muscles, calves, and other factors play an essential role when you are doing this exercise.

Squatting is a fundamental human movement pattern that involves nearly every muscle in the body. Squatting improves fitness, performance, and mobility for daily life tasks. Squat training gets various advantages, such as increase entire body strength, muscle, burn fat, improve circulation, get rid of cellulite. Furthermore, increase flexibility & prevent injuries, build core strength, build healthy bones and joints, maintain mobility and balance etc. [6].

Performing this exercise is not easy for any armature due to the difficulty of posing the correct technique and lack of strength and flexibility. However, squatting without correct technique or instructions may lead the player to severe injuries, disabled or paralyzed. Currently, some physical instructors and trainers properly train such techniques for squatting step by step. Also, there are demonstration videos on the internet to learn the correct techniques however it's not easy to find a recommended video due to the number of resources and even to follow and perform the correct technique. And to hire a personal trainer nowadays is much complicated and highly expensive.

Even the players may identify their faults in the techniques but to correct themselves without proper instructions or supervision by an instructor is much tricky. Through this project, any armature can identify their faults while doing squats and correct by themselves without any supervisor or physical trainer.

There is various kind of squat exercises. This research mainly focused on the free-weight back squat. This exercise can be performed using a barbell or dumbbells. Back Squat is the one every beginner should start.

In this paper, we use motion analysis to analysis the user motions of performing squats and to detect and identify whether it is performed with correct form or not. User can get results through the interface (mobile application). With this interface, the user can identify their own mistakes and can get instructions. After that user can correct their technical errors by themselves.

A. Effect of performing a squat exercise

The Squat is the most important and famous exercise in the world and the most straightforward exercise for every person. This exercise is essential to maintain their health as well as much important for trainers who involve sports such as athletes doing this by adding extra weights. Due to the issues with the techniques they are being carried out, most of the people get some terrible results. This project is for Minimizing injuries and common technique errors when performing the squat exercise. Some side effects of doing Squat with wrong techniques can be given as [3].

- Injuries
  - knee injuries
  - Back injuries may occur when deviating from a natural back arch
  - Neck or upper back injuries
  - Strain muscles, tendons and ligaments supporting the knee area
- Soreness.
- Muscular Imbalance.
- Flexibility Loss.
- Unintended Results

Moreover, the standard technique errors of squatting which are significantly identified, such as Lack of tightness during Lift-Off, heels coming off the floor, exaggerated knees-forward movement, and knees are moving inward. Also, some other technique errors are sitting on the thighs instead of between them, asymmetric lift-off, limp feet, and mornings half squats [2].

Many people do their workouts without instructors. Even in the gym, the instructor cannot concentrate on every single person personally. But every single person can do squat exercise anywhere without any equipment according to their opinion.

If there is any method to identify their own mistakes, anyone can perform squat with correct technique and minimizing the injuries at all. Thus, the proposed method, which is based on the computer vision system, is helped to achieve the above key features while performing this exercise.

The rest of the paper is organized as follows. Section II represents the proposed methodology. Section III discusses the obtained results, while Section IV presents the conclusion.

II. METHODOLOGY

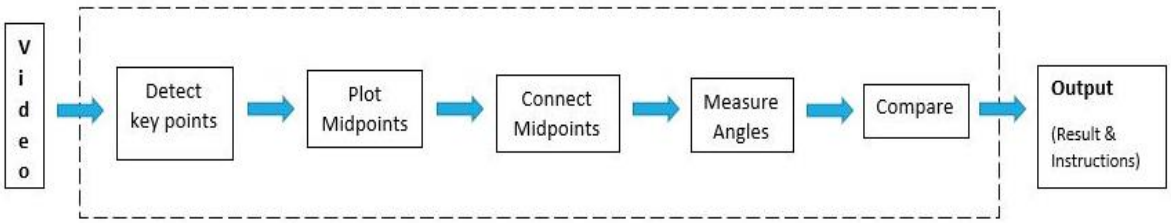

Fig 1:- Block diagram of the project process

From the video uploaded by the user, analyzing the front and the side view of the user who performs the squat exercise through image processing, the crucial key points [5], were identified as shown in Fig.1.

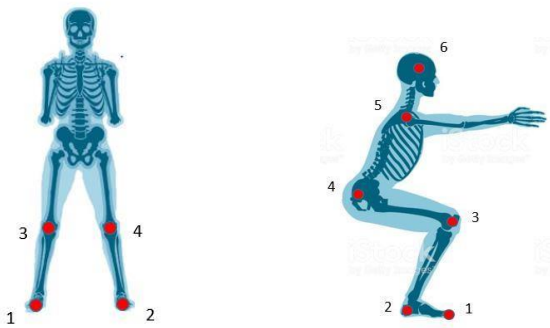

Fig 2:- Key points that should be considered by front and side view

Then the midpoints were labelled in each K-tape [1] of the user using a connecting grid, as shown in Fig.2. The midpoints are considered to increase accuracy by reducing the unnecessary area of the K-tape. Then the midpoints are connected, and angles between the key points have determined and compared with the conditions are described in Table 1. Furthermore, Fig.3, Fig.4, Fig.5 and Fig.6 are shown in specific positions more elaborately.

Position	Condition
Front (Clockwise -)	Considering point 1 and 3, $\beta \leq 0$. (during the cycle of motion) During the motion, the user should not be unbalanced.
Side (Clockwise +)	Considering point 1 and 3, point 3 should not exceed the Reference line (show in below) during the motion. Point 6 should be between point 5 and point 1.
Foot position	$\alpha 1$ and $\alpha 2$ should remain as an initial stage. ($\alpha 1 = 0$, $\alpha 2 = 0$)

Table 1:- Key points position and conditions

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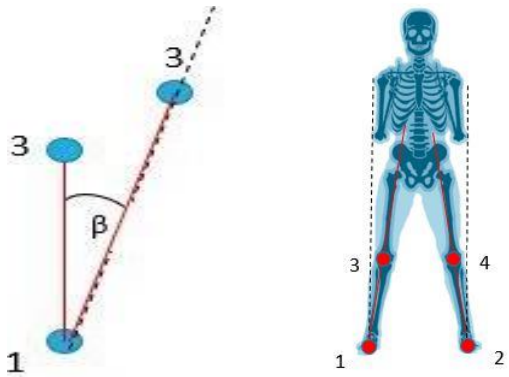

Fig 3:- $\beta \leq 0$ conditions in front clockwise (-)

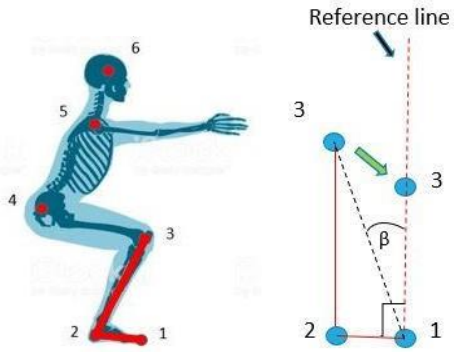

Fig 4:- Exaggerated knees-forward movement condition: side clockwise (+)

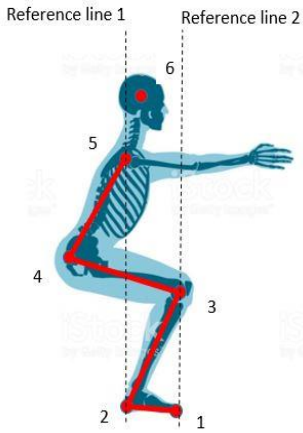

Fig 5:- Head position during the motion: side clockwise (+)

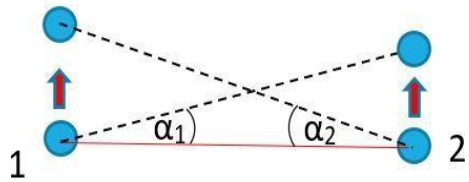

Fig 6:- Condition of foot position

If the above conditions are satisfied, then it is concluded as a correct squat. And if the conditions are not satisfied, i.e. if errors are there when performing, then instructions are given to correct the performing of the Squat.

III. RESULTS

From the correct performance of squats, three angles are identified as θ, ⋋, γ, and the user's motion was mentioned in Table 2.

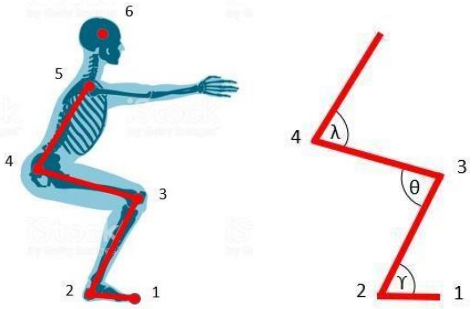

Fig 7:- Position of ⋋, γ and θ angles.

From the analysis, values of angles are collected and sorted according to 5 positions, namely “top”, “middle”, “bottom”, “between top and middle” and “between middle and bottom". i.e. for each position, there is a set of values for ⋋ and γ about θ.

θ_{ref}(deg)	λ(deg)	γ(deg)
165	157 - 177	90 - 98
135	114 - 120	80 - 85
100	86 - 105	72 - 77
90	73 - 80	69 -74
63	65 - 70	56 - 68

Table 2:- Range of λ, γ for 5 positions with reference to θ_ref

The OpenCV is used to identify the five positions. Also, the Vector function is used to determine the reference angles by using the Cosine rule. These angles are calculated at the knee, waist, and ankle. All these angles are calculated on the free-weight back squat exercise.

IV. CONCLUSIONS

The Squat is an exercise which is practiced by many athletes and sports personalities. But due to the incorrect techniques, there have been many situations where injuries have occurred. This project is focused on reducing these injuries by commenting and advising about the errors in the techniques used. The user has analyzed a video of the user when performing the squat exercise and checking whether the conditions of a correct squat are achieved by image processing, thus detecting key points to determine three specific angles at the foot, ankle and waist.

Furthermore, this project will help to build a database which will be profitable to the future enhancement and for other research projects regarding free-weight back squat with significant errors which are happening while performing squats. Also, since this research has conducted only for the free-weight back squat, this would make beneficiary for future researches regarding other exercises.

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