Joint Injury of Taijiquan Based on Computer Image Analysis

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With people’s attention to physical health and health preservation, more and more people practice Taijiquan to achieve the purpose of physical fitness and self-cultivation. However, many people do not fully understand the principles of Taijiquan in the early stage of practicing Taijiquan, rely on imitation to practice, and ignore the action essentials and characteristics of Taijiquan, resulting in joint pain. At the same time, many beginners ignore the causes of these situations, resulting in joint damage. Therefore, this paper proposes the research on the joint injury of Taijiquan based on computer image analysis and carries out the dependent research and analysis through the joint image processing model based on the improved Robert’s edge detection algorithm. The experimental results show that the action cycle time of wrong action is longer than the total time of correct action due to the increase of action displacement, and the long displacement distance increases the pressure on the knee joint and improves the probability of knee joint damage. In addition, there are obvious differences between wrong action and correct action in knee adduction and abduction, flexion and extension, internal rotation, and external angle. Wrong action knee joint movement does not conform to the natural movement law of human body, which increases the pressure or tension to the knee joint and surrounding related tissues and improves the probability of knee joint damage.

1. Introduction

With the improvement of people’s quality of life, people pay more and more attention to physical health and health preservation. As one of the national intangible cultural heritages, Taijiquan boxing is continuous and continuous and integrates elements such as martial arts, art, and traditional Chinese medicine, which can achieve the role of self-cultivation while strengthening the body. The movement situation of Taijiquan is mainly slow. In the movement process, it pays attention to the mutual cooperation of meaning, Qi and body, which can meet the physiological and psychological requirements of people of different ages and promote the development of human physical and mental health [1]. In addition, long-term Taijiquan practice is obviously helpful for the prevention and treatment of some chronic diseases. Some scholars intervened in the traditional Yang’s Taijiquan system training for 26 days for the middle-aged and elderly subjects with hypertension. The experimental results show that Taijiquan can improve the quality of life of patients with hypertension and promote the development of physical and mental health of patients [2]. Other scholars pointed out that the balanced and coordinated round and soft movement with blood shown by Taijiquan is consistent with the physiological law of the human body and can regulate and enhance the order of the Zang Fu organs and the functions of various systems of the human body [3]. Therefore, the value and significance of Taijiquan in fitness has been deeply recognized by people, and more and more people achieve the purpose of fitness by practicing Taijiquan.

However, many people do not have a comprehensive understanding of Taijiquan at the beginning of Taijiquan practice. They think that the movement speed is slow and stable, the action intensity is not large, and there is no excessive burden on the body. They ignore the requirements of Taijiquan practice related to the strength of lower limbs, resulting in knee pain during practice [4]. At the same time, beginners mainly focus on rough imitation practice at the beginning of learning and do not really master the essentials and techniques of Taijiquan. Therefore, they are confused about the phenomenon of joint pain symptoms in practice,
and even some learners ignore this situation, which aggravates the physical joint pain and causes joint injury [5]. Therefore, the correlation and influence of total wrong movements in Taijiquan practice on knee injury has become a hot spot of attention and research. Some scholars analyzed the causes of knee joint injury caused by Taijiquan from the perspective of knee joint movement mode, and pointed out that the relevant reasons include too low center of gravity, nonstandard technical movements, and lack of muscle strength [6]. Other scholars have studied the relationship between the knee joint injury caused by Taijiquan through the analysis of three straight and five Shun boxing theory in the Style Taijiquan and pointed out that understanding and mastering the boxing theory can effectively prevent the knee joint injury caused by Taijiquan [7].

This paper is mainly divided into four parts. The first section expounds the background research of Taijiquan regulating physical and mental health. Section 2 analyzes the characteristics of Taijiquan and the mechanism of knee injury. This paper expounds the characteristics of Taijiquan and the mechanism of knee joint injury. The third section is to establish the image analysis model of joint injury based on computer image analysis algorithm and construction of image analysis model of joint injury based on computer image analysis algorithm. This paper expounds the basis of computer image digitization. The fourth part is the analysis of the experimental results of Taijiquan joint injury based on computer images. The improved result of Robert’s edge detection algorithm. This paper presents the research of Taijiquan joint injury based on computer image analysis and processes the corresponding images through computer image algorithm, so as to provide more accurate and intuitive data for the later joint injury analysis.

2. Exercise Characteristics of Taijiquan and Mechanism of Knee Injury

Knee ligament relaxation will lead to instability of the knee because the ligament is the stable structure of the knee. If there is relaxation, the stable structure of the knee joint will be destroyed. This leads to the instability of the knee joint, when the patient later flexes and stretches the knee joint, or runs, jumps, and squats. It will lead to instability with obvious shaking of the knee joint. After learning and practicing Taijiquan, practitioners need to be able to have a calm mind, relaxed posture, move at a slow and uniform speed, and be flexible, natural, coordinated, and complete in the process of movement, with relaxed and soft movements running through the front and back [8]. The practice principle of Taijiquan also includes the concept of Taijiquan. It pays attention to the combination of Yin and Yang, deficiency and reality in the process of exercise. The action form includes unique forms of expression such as up, down, left, and right, inside and outside, advance and retreat. The practitioner should be able to sink Qi into the Dantian and follow his mind. In the process of Taijiquan practice, it is also necessary to understand, master, and apply the theory of three straight and five Shun boxing, that is, the practitioner should keep the head, body, and lower legs straight in the practice process, the head should not be tilted, the body should not swing around, the lower leg knees should not be too bent, and the crotch should be kept straight [9, 10]. Wushun refers to a natural law that conforms to the physiological structure and anatomical requirements of the human body, that is, when practicing Taijiquan, no matter what action should conform to the movement law of the human body, and the movement should be carried out within a reasonable range [11, 12]. However, if beyond this range, internal twisting, kneeling, and other movements will cause certain damage to the body of Taijiquan practitioners.

The hinge of human movement is the joint, which can produce activity between two or more bones [13]. In general, this connection can be divided into immovable joints and movable joints with liquid at the joint, but intervertebral joints and knee joints do not belong to these two categories [14]. The knee joint is a double ankle joint, including the lower femur, the upper tibia and the patella. As shown in Figure 1, it is the schematic diagram of the right knee joint. In addition, the knee joint includes a meniscus that can deepen the joint fossa and increase the flexibility and stability of the joint, the tendons of the quadriceps femoris surrounding the front and side of the patella, and the peroneal collateral ligament and tibial collateral ligament on both sides of the joint [15]. The knee joint has two motion axes that can move around the coronal axis and the vertical axis, which can make the knee joint flexion and extension and small internal and external rotation. When practicing Taijiquan, the knee joint relies on these two axes to complete different Taijiquan movements. Due to the characteristics of Taijiquan, the knee joint always maintains a state of flexion during the movement, that is, most of the movement of the knee joint is carried out around the vertical axis [16, 17].

Taijiquan exercise for a long time will lead to the problem of ligament relaxation of the knee joint that has been in the flexion state, so as to reduce its stability. It can only rely on the patella and quadriceps femoris to maintain the required
stability, which makes the patella and patellar ligament need to bear a lot of pressing pressure to support the weight of the practitioner’s body and complete the corresponding actions. Therefore, patellar strain, patellar ligament injury, and meniscus tear are common injuries in Taijiquan practice [18]. Among them, patellar strain and patellar ligament injury belong to chronic injuries, mainly because the continuous movement of the practitioner under the condition of excessive weight-bearing of the knee joint makes the subtle injuries accumulate repeatedly into injuries [19]. The meniscus tear is caused by the sudden reverse movement of the thigh or the sudden straightening of the knee joint when the knee joint remains in the flexion state and the lower leg is fixed in the abduction and external rotation state [20]. It can be seen that in the process of Taijiquan movement, when the movement is not standardized or does not conform to the law of human movement, it is easy to cause corresponding joint damage. In addition, the weak strength of the lower limbs of the exerciser will cause chronic injury caused by excessive weight-bearing of the knee joint.

3. Construction of Image Analysis Model of Joint Injury Based on Computer Image Analysis Algorithm

3.1. Fundamentals of Computer Image Digitization. With the development of computer technology and the expansion of image application field, computer image analysis technology has developed rapidly and has been widely used in many fields. In biomedicine, the application of computer image analysis technology improves the definition and resolution of images, provides a clearer number of images for doctors and related research, and is conducive to improving the accuracy of corresponding diagnosis and judgment. Before computer image analysis, it is necessary to discretize the continuous image, that is, convert the analog image into digital image through sampling and quantization and set the continuous image as $f(x, y)$. Image digitization is the process of converting analog images with continuous spatial distribution and brightness distribution into digital images that can be processed by computer through sampling and quantization. To process images in the computer, we must first convert the real images (photos, pictorials, books, drawings) into the display and storage format that the computer can accept through digitization and then use the computer for analysis and processing. The process of image digitization is mainly divided into three steps: sampling, quantization, and coding. After digital processing, the matrix $g(i, j)$ can be obtained, which is composed of discrete quantities, as shown in the following formula:

$$
g(i, j) = \begin{bmatrix}
    f(0, 0) & f(0, 1) & \ldots & f(0, n-1) \\
    f(1, 0) & f(1, 1) & \ldots & f(1, n-1) \\
    \vdots & \vdots & \ddots & \vdots \\
    f(m-1, 0) & f(m-1, 1) & \ldots & f(m-1, n-1)
\end{bmatrix}, \quad (1)
$$

where $g(i, j)$ represents the luminance value of each element and $0 \leq g(i, j) < \infty$.

During image sampling, if the number of horizontal pixels is $M$ and the number of vertical pixels is $N$, the size of the image can be expressed as $M \times N$. The selection of sampling interval has an impact on the image quality after sampling. The smaller the sampling interval, the more details will be reflected. According to the correlation theorem, if the one-dimensional signal is expressed as $g(t)$, its maximum frequency is expressed as $\omega$, and the sampling interval is selected as $T \leq 1/2\omega$, $g(t)$ can be completely recovered through the sampling results, as shown in the following formula:

$$
g(t) = \sum_{i=\infty}^{\infty} g(iT)s(t - iT). \quad (2)
$$

The sampling result is expressed as $g(iT), i = \ldots, -1, 0, 1, \ldots$, $s(t)$ as shown in the following formula:

$$
s(t) = \frac{\sin(2\pi\omega t)}{2\omega t}. \quad (3)
$$

Although the sampled analog image is a discrete pixel in time and space, its pixel value is still a continuous quantity, and the process of transforming the gray value of each pixel into a discrete quantity is the quantization of image gray. Sampling points and quantization stages of each pixel in the quantization process have an impact on the quality of digital image and the amount of data. Image sampling is to divide a spatially continuous analog image into a network of $m \times n$, which is called the spatial resolution of the image. According to Shannon sampling theorem, as long as the sampling frequency is greater than twice the maximum frequency of signal sampling, the original signal can be completely restored by the sampling signal. In addition, in biomedical applications, the image edge in the basic image features has a certain impact on image processing and image digitization. It exists in the boundary between the required targets, between the target and the background, and between the primitives, which can reflect the actual content of the required targets. However, the traditional image edge detection algorithm in practical application will be affected by the uneven illumination and noise of the edge part, and the accuracy of determining the image edge position is poor. In this way, it will cause some analysis errors when analyzing the joint image. Therefore, the improved Robert edge detection algorithm is selected as the computer image analysis algorithm in this paper.

3.2. Edge Detection Algorithm Based on Robert and Its Improvement. In the traditional Robert edge detection algorithm, the gradient is replaced by the difference between two adjacent pixels in the diagonal direction. The gradient is calculated as shown in the following formulas:

$$
f_x = f(i, j) - f(i + 1, j + 1), \quad (4)
$$

$$
f_y = f(i, j + 1) - f(i + 1, j), \quad (5)
$$

where the convolution operator of gradient is shown as
The gradient amplitude is calculated as shown in the following formula:
\[ R(i, j) = \sqrt{f_x^2 + f_y^2}. \]  
(7)

Or its approximation is shown in the following formula:
\[ R(i, j) = |f_x| + |f_y|. \]  
(8)

From the above formula, it can be obtained that the approximate value of the continuous gradient amplitude displayed by the Robert operator at the difference point \((i + 1/2, j + 1/2)\) is \(R(i, j)\). If the selected threshold is expressed as \(\tau\) and when \(R(i, j) > \tau\), the point \((i, j)\) is the edge point.

From the above process, it can be seen that the traditional Robert algorithm mainly relies on diagonal adjacent pixels in gradient detection and ignores horizontal and vertical adjacent pixels, so it is highly sensitive to noise. At the same time although detailed edges can be obtained through the traditional Robert algorithm, when the noise interference cannot be eliminated, it will also lose the detection of the local edges with slow gray value change, resulting in the discontinuous state of the contour edge of the target. The threshold setting of the traditional Robert algorithm needs to be set manually, and the threshold setting cannot be determined by the image feature information, so it has a low degree of automation. In addition, in some special needs scenarios, the traditional Robert algorithm still cannot meet the needs, so the traditional Robert algorithm needs to be improved accordingly.

In view of the problems existing in the gradient amplitude calculation of the traditional Robert algorithm, this paper determines the pixel gradient amplitude through the first-order partial derivative finite difference of the pixel horizontal, vertical, 135 degrees, and 45 degrees and adds the corresponding weights to the 135 degrees and 45 degrees. It can meet the requirements of edge positioning accuracy and noise reduction at the same time. The calculation method is shown in the following formulas:

\[ P_0[i, j] = I[i - 1, j] - I[i + 1, j], \]  
(9)

\[ P_{90}[i, j] = I[i, j - 1] - I[i, j + 1], \]  
(10)

\[ P_{135}[i, j] = 2 \times (I[i - 1, j - 1] - I[i + 1, j + 1]), \]  
(11)

\[ P_{45}[i, j] = 2 \times (I[i + 1, j - 1] - I[i - 1, j + 1]). \]  
(12)

The corresponding convolution operator is shown in the following formula:

\[
\begin{bmatrix}
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{bmatrix}
\]  
(13)

The gradient amplitude and direction in rectangular coordinates are transformed into polar coordinates through second-order norm. The calculation method is shown in the following formula:

\[ M(i, j) = \sqrt{P_0^2[i, j] + P_{90}^2[i, j] + P_{135}^2[i, j] + P_{45}^2[i, j]}, \]  
(14)

Put the formula (14) as simplified formula:

\[ M(i, j) = |P_0[i, j]| + |P_{90}[i, j]| + |P_{135}[i, j]| + |P_{45}[i, j]|. \]  
(15)

By applying the idea of neighborhood average gray level, the improved Robert algorithm can automatically generate the threshold and automatically calculate the threshold of the point to be detected, as shown in the following formula:

\[ x = \frac{1}{9} \times \sum_{i=0}^{2} \sum_{j=0}^{2} I(i, j). \]  
(16)

In edge detection, if the threshold setting is fixed, it is easy to produce false edges when the threshold setting is too small; if the threshold is set low, it is easy to make the edge discontinuous. Therefore, this paper automatically calculates the threshold through formula as follows:

\[
g(x) = \begin{cases} 
-0.009549x^2 + 30, & 0 \leq x \leq 48, \\
-0.000641x^2 + 0.162794x + 1.662554, & 48 < x \leq 206, \\
-0.017493x^2 + 8.921283x - 1087.463557, & 206 < x \leq 255. 
\end{cases}
\]  
(17)

4. Analysis of Experimental Results of Joint Injury Caused by Taijiquan Based on Computer Image

4.1. Improved Results of Edge Detection Algorithm Based on Robert. As shown in Figure 2, the complexity of Robert’s edge detection algorithm before and after improvement is compared. When performing edge detection and thinning on different images, the distribution of edge points is different. From the results in the figure, it can be seen that before Robert’s edge detection algorithm is improved, the number of operations in the best case is six and the number of operations in the worst case is eleven. The operation times of the improved Robert’s edge detection algorithm are four in the best situation and maintained at three times in both the best and worst conditions. The multiplication times of the improved Robert’s edge detection algorithm are four in the best situation and eight in the worst situation, while the multiplication times of the improved Robert’s edge detection algorithm are zero. It can be seen that the complexity of the multiplication operation times after the improvement is much lower than that before the improvement, has good stability, and does not affect the operation results of the original algorithm while ensuring the improvement of operation efficiency.

As shown in Figure 3, the effect of Robert’s edge detection algorithm on the thinning of knee joint image before and after improvement is compared. It can be seen from the
figure that the improved Robert’s edge detection algorithm can reduce the impact of noise, refine better, detect weak edges, and show more details. Therefore, the improved Robert’s edge detection algorithm has better performance.

4.2. Analysis of Experimental Results of Joint Injury Caused by Taijiquan. The experimental object of this paper is a 48-year-old female. The practice time of Taijiquan is 14 years. According to the action characteristics of Taijiquan, the experimental action is divided into three stages, that is, moving forward is the first stage, sitting back is the second stage, and turning feet is the third stage. As shown in Figure 4, the comparison of the average time test results of the time spent in different stages by the subjects’ high and low correct actions and wrong actions is shown. It can be seen from the data in the figure that the time for correct action is significantly shorter, whether it is the time spent in different stages or the total time spent in an action cycle. From the time spent in different stages, compared with the

![Figure 2: Comparison results of the complexity of Robert’s edge detection algorithm before and after improvement.](image)

![Figure 3: Comparison of the effect of Robert’s edge detection algorithm on the thinning of knee joint image before and after improvement. (a) Traditional Robert’s edge detection algorithm. (b) Improved Robert’s edge detection algorithm.](image)
time spent in different stages of wrong actions, the percentage of time spent in the first stage and the second stage in the total time is higher than that in the wrong stage. This shows that the correct action takes more time to move forward and sit back, while the time for turning the foot is shorter, while the wrong action takes less time in the first two stages and takes longer in the turning stage. From the comparative analysis of movements, it is found that the wrong movement moves the right knee farther forward in the first stage, which lengthens the displacement distance of turning the center of gravity from the right to the left in the second stage, so that the time of the first two stages is long. At the same time, the wrong action has excessive torsion of the right foot in the third stage, which prolongs the time of the third stage.

When practicing Taijiquan, the knee joint angle in the high position is maintained in the range of 110 degrees to 130 degrees, as shown in Figure 5. It is the comparison result of the flexion and extension angle of the right knee joint in the correct and wrong movements of the practitioner. As can be
seen from the figure, the knee joint will produce sagittal flexion in the first stage. When the right foot lands, the knee joint in the correct action is in the state of bending the knee, while the knee joint in the wrong action is in the state of extending the knee. And the difference of knee flexion angle between the two action states will gradually increase with time and action, so that the difference of flexion and extension angle between correct action and wrong action reaches the maximum in the second stage. The normal range of motion of the knee is 135 degrees flexion, 0 degrees extension, and 10 degrees overextension. If the patient’s overextension is obvious, knee reflex may occur. Active knee flexion and passive knee flexion can reach 135 degrees and 160 degrees, respectively. At this time, the knee joint in the correct action is in the normal range of motion of the knee joint, and the force borne by the surrounding ligament tissue is small, so it is not easy to cause damage. The knee joint in the wrong action has a large extension angle at this time, and there is a certain degree of overextension. Please exert great pressure on the ligament tissue and posterior muscles on both sides of the knee joint, which is easy to cause injury. In the first two stages, there are obvious differences in action angle and action cycle between correct action and wrong action, but there is no significant difference between them in the stage of turning feet.

As shown in Figure 6, it is the comparison result of the addition and abduction angle of the right knee joint in high position between correct and wrong movements. As shown in Figure 7, it is the comparison result of the internal rotation external angle of the right knee joint in the high position between the correct movement and the wrong movement of the practitioner.
practitioner. It can be seen from the figure that there is no obvious difference between the correct action and the wrong action in the recoil stage, but in the first stage, the external rotation angle of the wrong action is greater than that of the correct action, which increases the pressure on the medial ligament of the knee joint of Taijiquan practitioners, thus improving the probability of knee joint damage. At the same time, the wrong angle makes the toe abduction angle too large in the process of turning the foot, which has an obvious gap between the correct actions. Excessive external rotation will produce too much pressure on the knee joint, so as to reduce the balance of the practitioner, which is easy to cause knee sprain and so on.

To sum up, whether in the action cycle time or the time used in different stages of the wrong action, the wrong action increases the action time due to the increase of knee displacement, and there is the problem of excessive rotation of the right foot. In the high position movement, the knee joint with correct action is always in the flexion state, which is in line with the law of human movement. However, there are obvious differences between the flexion and extension, adduction and abduction, external rotation angle, and correct action of the knee joint with wrong action, which increases the probability of knee joint damage.

5. Conclusion

This paper presents the research of Taijiquan joint injury based on computer image analysis and processes the knee joint image based on the improved Robert edge detection algorithm, which provides a clearer image basis for future research and analysis. In the action cycle, the time of wrong action is longer than that of correct action, and it is too long in the foot turning stage. This is mainly due to the increase of displacement distance caused by action error. At the same time, the increase of displacement distance will also produce excessive pressure on the knee joint and ligament tissue. In addition, there are obvious differences between the wrong action and the correct action in adduction, abduction and pronation, which makes the high position of the knee joint too inconsistent with the law of human movement, and it is easy to cause damage by bearing greater pressure or tension on the knee joint, medial muscles, and ligaments. To sum up, whether in the action cycle time or the time used in different stages of the wrong action, the wrong action will increase the action time due to the increase of knee displacement, and there is the problem of excessive rotation of the right foot. In high-level movement, the knee joint with correct action is always in a flexion state, which conforms to the law of human motion. However, there are obvious differences between knee flexion and extension, abduction and adduction, external rotation angle and correct and wrong movements, which increases the probability of knee injury.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

References


