ORIGINAL ARTICLE PEER REVIEWED | OPEN ACCESS

# Correlation between knee related injury and biomechanics in distance runners

I Gusti Ngurah Wien Aryana, Ida Ayu Arrisna Artha

## ABSTRACT

**Running is a modality with a great number of practitioners in Indonesia, both due to its easiness of practice and its health benefits and low cost involved. The knee is the most common site of overuse running injuries, accounting to close 50% of all injuries. The cause of running related injuries include inadequate muscle strength and flexibility, structural or functional abnormalities, inappropriate running surfaces, overuse or overtraining, improper shoes, and inefficient running mechanics. The purpose of this study was to identify biomechanical and anthropometric variables that contribute to knee related injury in runners. Comparisons were made between a group of runners who had sustained knee pain in running injury and a group of runners who had been knee pain free throughout their running careers. Group were well matched in important training variables such as anthropometric and biomechanics variables. The knee pain demonstrated significantly greater weekly mileage, poor hamstring flexibility, greater Q-angle, longer stride length, heel strike and over pronation of foot. The results of the present study suggest that subjects who utilize a running stride characterized by relatively low impact forces and a moderately rapid rate of pronation are at a reduced risk of incurring overuse running injuries stride length, also characterized as step length. There are few, if any, significant associations between gait, strength, and anthropometrics and injury frequency. Most of these risk factors could potentially be modified to reduce joint loads to lower the risk of injury.**

**Keywords: Biomechanical factors, Knee injuries, Runner**

How to cite this article

IGN Wien Aryana, IA Arrisna Artha. Correlation between knee related injury and biomechanics in distance runners. Edorium J Orthop 2019;5:100011O03WA2019.

Article ID: 100011O03WA2019

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doi: 10.5348/100011O03WA2019OA

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Received: 14 September 2018
Accepted: 21 January 2019
Published: 18 February 2019

## INTRODUCTION

Running is a popular form of recreational exercise in Indonesia. Epidemiologic studies indicated that running reduces the threat of some chronic disease, decrease disability and pain, and lowers healthcare costs. Unfortunately, these benefits can be offset by annual overuse injuries that cause as many as 65% (range = 46-65%) of all runners to stop running and to seek treatment [1]. Running is one of the most widespread activities during which overuse injuries of the lower extremity occur. Various epidemiological studies have estimated that anywhere from 27% to 70% of recreational and competitive distance runners sustain an overuse running injury [1, 2, 3]. Analysis of prospective and retrospective survey studies and cohort studies of recreational and competitive runners reveals a yearly incidence of injuries in runners of 24–85% [4].

The cause of running-related injuries include inadequate muscle strength and flexibility, structural of functional abnormalities, in appropriate running surfaces, overuse or overtraining, improper shoes, and inefficient running mechanics. Risk factors of injury in any sport may be categorically divided into extrinsic or intrinsic. Behavioral (e.g., training history, injury history) and physiological (e.g., quadriceps and hamstring flexibility, Q-angle, arch height, strength) risk factors are thought to interact with Running Related Injury. Cowan et al. followed 246 army recruits with no history of injury and found that those with cavus feet had a higher injury risk than those with normal or planus feet (odds ratio [OR] = 6.12) [5]. Messier et al. found that a Q-angle over 16° and a high arch were associated with anterior knee pain. Stride length, an important variable in physiological efficiency, has also been linked to impact forces during running [6]. Mercer et al. found that overstriding by 15% of freely chosen stride length increased peak leg accelerations compared with normal stride length and understriding by 15%. Over thousands of strides, the increased shock to the lower extremity may result in overuse injury [7].

The knee is the most common site of overuse running injuries, accounting for close to 50% of all injuries. A recent systematic review and meta-analysis reported that the knee was the most common site of musculoskeletal injury for runners [8]. According to a clinical study of more than 2000 injured runners, the most common knee condition is patellofemoral pain syndrome (PFPS), followed by iliotibial band syndrome (ITBS), meniscal injuries, and patellar tendinitis. Injuries to the foot, ankle, and lower leg—such as plantar fasciitis, Achilles tendinitis, and medial tibial stress syndrome (also known as shin splints)—account for almost 40% of the remaining injuries, whereas less than 20% of the running injuries occur superior to the knee. Although few overuse running injuries have an established cause, more than 80% of these injuries occur at or below the knee, thus suggesting that some common mechanisms may be involved [9].

The objectives of this investigation were 1) to ascertain the incidence, recurrence, severity, body site, and exposure setting of running-related lower-extremity injuries prospectively among a runner and 2) to identify anthropometric and training-related risk factors associated with these injuries.

## MATERIALS AND METHODS

The research conducted was cross-sectional study.

### Study population

A total of 55 recreational runners were recruited from local running club. These subjects were divided into two groups, knee injury free (21) and knee injured (34). The inclusion criteria was age greater than 18, running more than 10 km/week. Exclusion criteria was chronic diseases or orthopedic conditions and pregnancy. To minimize the influence of injuries from other sports, subjects who regularly (more than four times/week) trained or participated in aerobics, dancing, basketball, volleyball, and racquet sports were excluded from the study. Informed consent was obtained for each subject prior to participation.

### Data Collection

Height and weight were recorded and completed a standardized questionnaire included current running mileage, past and current musculoskeletal injuries related to running stretching and warming up habits, years of running experience,workout intensity (average training pace), typical running surface, shoes worn and three-dimensional gait analysis and anthropometric measurements.The data was obtained with SPSS/PC+ 4.0 statistical package.

The quadriceps angle (Q-angle), hamstring flexibility, quadriceps flexibility were measured using standard methods. For Q-angle, runners were instructed to stand comfortably (without shoes) with knees extended and quadriceps muscles relaxed, feet facing anteriorly approximately shoulder-width apart, and with body weight distributed evenly across both legs. A standard full-circle goniometer with lengthened stationary arms was used. Hamstring flexibility was measured with the subject supine, and the hip and knee flexed to 90°. While maintaining the 90° flexed hip, the subject extended the knee as far as possible. Quadriceps flexibility was measured with the subject lying prone with both legs strapped to the examining table.

Body weight, height, and Body Mass Index (BMI) were measured using standard techniques. Body weight was, obtained without shoes or jackets. BMI was calculated using the formula BMI weight (kg)/height2 (m).

Observations should be made from the front, back and side with the subject on a runway or on a treadmill with zero incline. The patient should warm-up and then self-select the walking or running speed. We analyzed rearfoot angle, foot strike and stride length.

In this study, Knee Injury was defined as pain on knee joint not caused by an external event, such as a fall, that produced pain or discomfort and caused (a) reduced weekly mileage and/or training intensity (number of days/wk, time per session, or pace); (b) cessation of running for at least one week; or (c) needed to seek medical attention.

## STATISTICAL ANALYSIS

All training variables were analyzed first, and separately, to determine whether the groups were actually matched in important training variables within limits of statistical significance. To accommodate statistical procedures, all dichotomous training variables were assigned a value of zero for a “no” answerand a value of one for a "yes" answer. There was no need to make adjustments to continuous variables. All variables were compared between groups using a multivariate analysis of variance (MANOVA), with the significance level set at a < 0.05. If the groups were deemed to be sufficiently matched in training variables, anatomical and biomechanical variables would be compared between groups, using a similar MANOVA procedure to test for differences between groups in the mean values of the dependent variables.

## RESULTS

The results of the present study suggest that subjects who utilize a running stride characterized by relatively low impact forces and a moderately rapid rate of pronation are at a reduced risk of incurring overuse running injuries (Figure 1) (Tables 1 and 2). Stride length, also characterized as step length in some literature, is the distance between successive ground contacts of each foot. Research in this area has provided evidence that runners, given the option to run at a self-selected stride length, tended to choose a stride close to their most metabolically efficient running length.

## DISCUSSION

Numerous studies on runners have found links between overuse injuries and a variety of risk factors including kinematic, kinetic, anthropometric, and strength variables. Although results have been mixed, the general trend is that those who develop overuse injuries less frequently.

The causes of overuse running injuries have not been identified, but the etiology is clearly diverse. Previous studies have identified relationships between potential risk factors and a variety of injuries, with the knee being the most common injury site. We provide further insight by exploring the relationship between potential biomechanics and knee injury, which we consider to be potential mechanisms of overuse knee injuries in runners.

The literature generally suggests that greater weekly mileage increases the risk of overuse injury, although contradictory results exist [4, 10–13]. Our results associate greater weekly mileage with knee injury.

Running is composed of two phases, the swing phase, when the leg is in the air, and the stance, or support phase, when the leg is on the ground. The beginning of the stance phase and the end of the swing phase are characterized by the contact of the foot with the ground. The stance phase is further divided into the initial impact phase, when the foot initializes contact with the ground and the propulsive phase, or toe off, when the foot terminates contact with the ground [14, 15]. In studies of joggers, runners, and sprinters, threefoot strike styles have been identified. Style identification is determined by what part of the foot strikes the ground first: the heel, the midfoot, or the forefoot. The most predominant style is that of heel striking, with approximately 80% of the running population leading with their heels as they strike. Midfoot striking, the second most predominant style, consists of landing on the ball of the foot, while forefoot striking, the least common, consists of landing toward the toes [16–18].

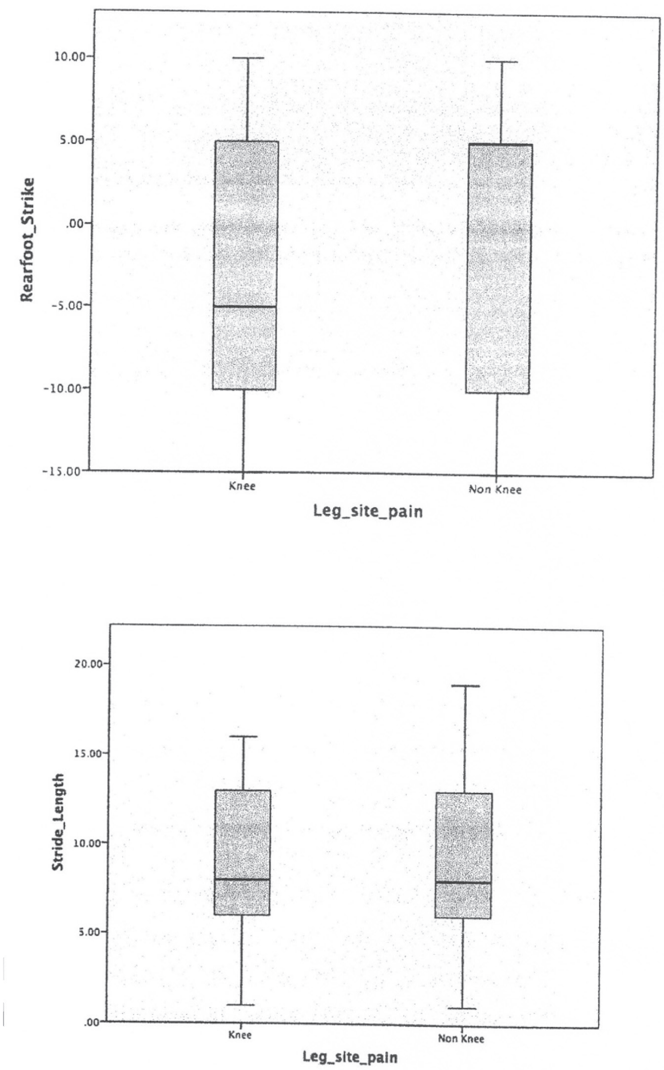


Figure 1: Box plot of rear foot strike angle and stride length in runners with pain around knee area and non-knee area.

The biomechanics of running is composed of mechanical variables that include foot strike position, stride length, stride rate, knee angle at foot strike, and maximal knee flexion angle during support [19]. Poor hamstring flexibility was associated with higher knee extension moments. Maximum knee extension moment occurs just before midstance, when the knee is maximally flexed. This moment functions kinematically to stop the knee flexion and the downward motion of the runner and then to extend the knee joint in propelling the runner upward and forward [20].

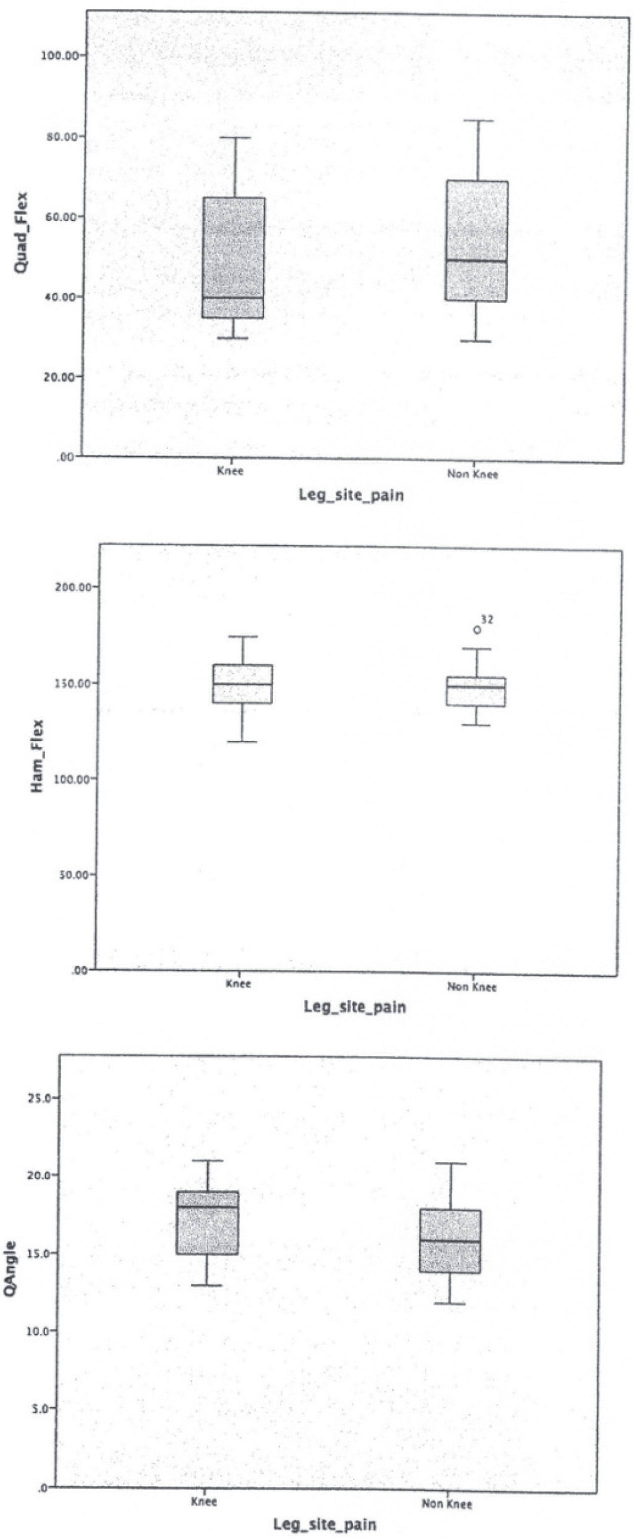


Figure 2: Box plot of rear quadriceps flexion angle, hamstrings flexion angle, and Q angle in runners with pain around knee area and non-knee area.

This moment was also significantly related to higher patellofemoral and tibiofemoral forces. Joint stiffness is a function of a change in knee extensor moment relative to a change in joint angle; hence, poor flexibility could affect changes in joint angle and the knee extensor moment, increasing joint stiffness and knee joint forces [21]. Consequently, poor hamstring flexibility would be detrimental to joint function by increasing joint stiffness and reducing the contribution of the knee to shock attenuation after heel strike. Lack of flexibility may increase the stiffness of a muscle, possibly placing more stress on the adjacent joints [22]. Poor flexibility could also be indicative of a muscular imbalance, which would facilitate the earlier onset of fatigue, thereby leading to improper mechanics during the latter stages of a run. Interestingly, there is no experimental evidence to demonstrate that stretching before or after running reduces the risk of overuse injuries. Maintaining flexibility of the hamstrings may be important in preventing overuse running injuries, while the use of stretching as a means of warm up or cool down is not effective in reducing overuse injury risk [23].

Messier et al. found that a Q-angle over 16° was associated with anterior knee pain [24]. Similarly, in an army cohort, a Q-angle in excess of 15° was identified as a risk factor for such injuries as stress fracture and nonacute muscle strain [25]. However, Duffey et al., using a much larger sample size than in the Messier study, found no relationship between Q-angle and runners with knee pain [26]. Similarly, Caylor et al. found slightly greater but nonsignificant differences between patients with and without knee pain [27]. Our results showed no significant relationships between Q-angle and any of the force or moment potential risk factors (Figure 2).

Cavanagh and Williams found that the self-selected stride length on average to be within 4.2 cm of the stride that is metabolically, most efficient for that runner [28]. Greater vertical thrusts corresponded with longer stride lengths, where these greater thrusts, or pushoffs, were indicative of the subjects leaving the ground. The implications of these studies support the contention that the knee joint acted as a shock absorber to handle the stress moving through the system. The data indicated that the longer the stride length, the greater the impact loads, the more the knee must act to attenuate the shock moving through the system. In essence, the longer the stride length, the greater the impact.

Pronation is a combination of ankle dorsiflexion, rearfoot eversion, and forefoot abduction, and it occurs during the first half of the stance phase in running. Excessive rearfoot frontal plane motion (eversion) influences lower extremity mechanics via tibial rotation. Because pronation during stance is necessary to dissipate stress, it is possible that the increased pronation noted by other researchers was a protective mechanism designed to attenuate high-impact forces. ln actual fact, high impact forces over a prolonged period of time may have been a major contributing factor to the injuries [29]. It is conceivable that a higher level of pronation is favorable during running, provided that it falls within "normal" physiological limitations. Generally, pronation allows forces to be attenuated over a longer period of time, although it has been stated that pronation must end

Table 1: Baseline characteristics of runners recruited for the study

| Variables | N (%) | Mean ± SD | Range |
|---|---|---|---|
| Age | | 31.54 ± 8.17 | 19.00–44.00 |
| 20–29 | 21 (37.5) | | |
| 30–39 | 22 (39.3) | | |
| 40–49 | 12 (21.4) | | |
| Sex | | | |
| Male | 36 (65.5) | | |
| Female | 19 (34.5) | | |
| Weight (kg) | | 63.85 ± 10.53 | 48.00–92.00 |
| < 50 | 5 (8.9) | | |
| 50–65 | 26 (46.4) | | |
| 66–80 | 20 (35.7) | | |
| > 80 | 4 (7.1) | | |
| BMI (kg.m2) | | 187.36 ± 83.84 | 19.00–324.00 |
| 20–29 | 1 (1.8) | | |
| 30–39 | 48 (85.7) | | |
| 40–49 | 5 (8.9) | | |
| > 50 | 1 (1.8) | | |
| Weekly miliage | | | |
| 1–10 | 12 (21.4) | | |
| 11–20 | 22 (39.3) | | |
| 21–30 | 6 (10.7) | | |
| > 30 | 15 (26.8) | | |
| Site Injury | | | |
| Knee Injury | 34 (60.7) | | |
| Non Knee Injury | 21 (37.5) | | |

Table 2: Comparison of anthropometric evaluation between the two groups

| Variables | p-value | Knee Injury (n=34) (Mean ± SD or n (%)) | Non Knee Injury (n=21) (Mean ± SD or n (%)) |
|---|---|---|---|
| Hamstring Flexibility | 0.016 | 152.05 ± 11.87 | 148.80 ± 13.36 |
| <140 | | 11 (32.4) | 3 (14.3) |
| 140-160 | 0.018 | 22 (64.7) | 13 (61.9) |
| 160-180 | | 1 (2.9) | 5 (23.8) |
| Quadriceps Flexibility | 0.000 | 49.26 ± 16.28 | 53.09 ± 18.06 |
| <40 | | 24 (70.6) | 2 (9.5) |
| 41-50 | | 5 (14.7) | 3 (14.3) |
| 51-60 | 0.000 | 4 (11.8) | 3 (14.3) |
| >61 | | 1 (2.9) | 13 (61.9) |
| Q-Angel | 0.000 | 17.05 ± 2.32 | 16 ± 2.46 |
| <16 | | 2 (5.9) | 17 (81.0) |
| >16 | 0.000 | 32 (94.1) | 4 (19.0) |
| Stride Length | 0.160 | 8.91 ± 4.54 | 9.00 ± 5.19 |
| 0.5-1 | | 13 (38.2) | 16 (76.2) |
| 1-2 | 0.158 | 21 (61.8) | 2 (9.5) |
| 2-3 | | 0 (0) | 3 (14.3) |
| Rear footangle | 0.001 | -3.64 ± 8.28 | -1.66 ± 8.56 |
| (-15)-(-5) | | 19 (55.9) | 3 (14.3) |
| (15)-5 | 0.002 | 14 (41.2) | 15 (71.4) |
| 6-15 | | 1 (2.9) | 3 (14.3) |
| Foot Strike | 0.001 | | |
| Heel | | 17 (50) | 1 (4.8) |
| Midfoot | 0.001 | 9 (26.5) | 9 (42.9) |
| Forefoot | | 8 (23.5) | 11 (52.4) |

before midstance to allow the foot to become more rigid for push off. Severe overpronators may be at an increased risk of injury due to the large torques generated and the potential instability associated with running in this style [30]. Severe overpronators, or runners who exhibit prolonged pronation, may be at an increased risk of injury because of the potentially large torques generated within the lower extremity and the subsequent increase in internal tibial rotation [31]. Excessive pronation, pronation velocity, and time to maximum pronation have often been implicated as contributing factors to overuse running injuries [4, 11].

The results of this study suggest that subjects who utilize a running stride characterized by relatively low impact forces and a moderately rapid rate of pronation are at a reduced risk of incurring overuse running injuries stride length, also characterized as step length in some literature, is the distance between successive ground contacts of each foot.

Adhering to a running program lowers the rate and progression of disability, risk of chronic disease, and mortality rates. Unfortunately, these health benefits are partially counteracted by the high risk of injury, with annual rates of up to 65% of all runners (range = 46-65%). Hreljac stated that although the cause of these injuries is unknown, they are clearly multifactorial and diverse [32]. Noakes indicated that physicians often treat overuse injuries with rest, drugs, injections, and surgery, often relying on clinical experience and failing to get to the root cause and treat it. This failure is due, in part, to the lack of large-scale clinical trials that test interventions to prevent or rehabilitate common overuse running injuries [33]. Our study is a first step in identifying mechanisms of injury that can later be tested in clinical trials. We found that larger knee joint loads were related to poor hamstring flexibility, higher BW, greater weekly mileage, and greater muscular strength. Most of these risk factors could potentially be modified to reduce knee joint loads to lower the risk of injury.

## CONCLUSION

In conclusion, running is an activity that has consistently produced a high incidence of knee related injuries. The majority of knee injuries are a consequence of the stress associated with overuse and overload. Running style does contribute to the stress accumulation in the knee joint. The musculoskeletal system can withstand a limited amount of stress before it reaches its limits and an injury occurs. Options to extend the life of these systems and decrease the possibility of injury must be explored. Changing the biomechanical variables that influence a running style is such an option, specifically when directed to heel strikers. By virtue of their biomechanics, these runners stress their musculoskeletal systems and their knee joints over and above the other types of runners.

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## Author Contributions

I Gusti Ngurah Wien Aryana – Substantial contributions to conception and design, Acquisition of data, Drafting the article, Revising it critically for important intellectual content, Final approval of the version to be published

Ida Ayu Arrisna Artha – Substantial contributions to conception and design, Analysis and interpretation of data, Drafting the article, Final approval of the version to be published

## Guarantor of Submission

The corresponding author is the guarantor of submission.

## Source of Support

None.

## Data Availability

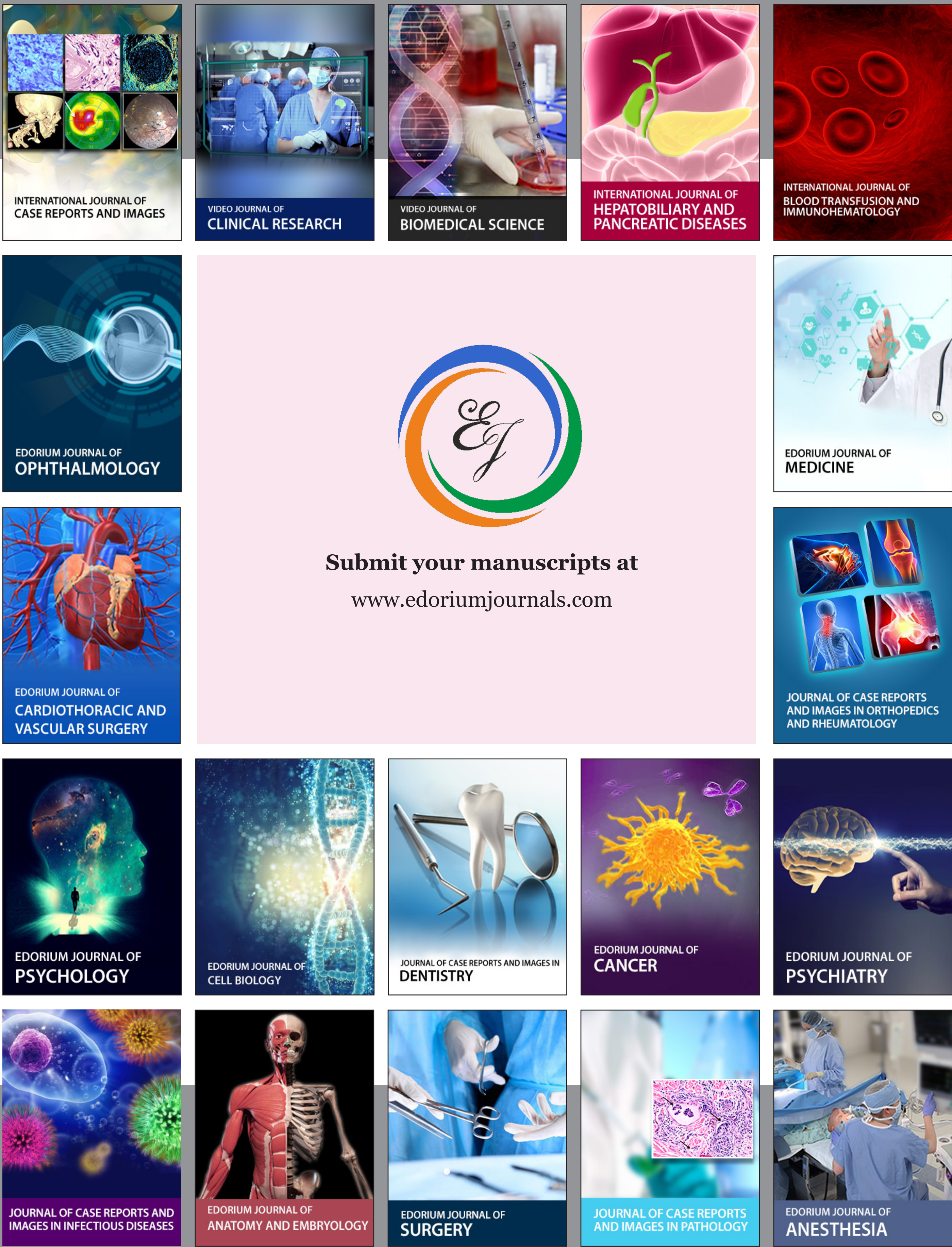
All relevant data are within the paper and its Supporting Information files.

## Conflict of Interest

Authors declare no conflict of interest.

## Consent Statement

Written informed consent was obtained from the patient for publication of this study.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