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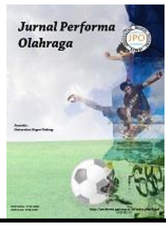

BIOMECHANICAL ANALYSIS OF THE GOLF SWING AND RISK OF LOW BACK PAIN IN GOLFER

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ABSTRACT

Lateralization in golf can increase muscle imbalances and the risk of low back pain (LBP). This condition needs attention, considering the high prevalence of injuries in the lower back and/or lumbar spine area, 15-35% in amateur golfers. Biomechanics analysis during a golf swing are believed to be one way to prevent LBP. Therefore, this study aims to determine whether the stages of the golf swing can increase LBP risk through an evidence-based case report. The search was carried out on 3 databases, Pubmed, Cochrane, and Scopus, and hand searching with PRISMA from March 3-10th, 2024. 9 articles were obtained which were then reviewed. Flexion speed, length of transition phase, onset time and muscle strength, such as erector spinae (ES), oblique externus (EO), latissimus dorsi (LD), X factor, crunch factor, swing plane and clubhead trajectories, and sequences and angles kinematics during swing can potentially influence the occurrence of LBP. A golfer's posture and muscle imbalances, along with poor swing technique, will increase existing risks. However, there are no conclusive evidence to support the belief that golf swing biomechanical factors are strongly related to LBP. There is a need for further research with better study design related to this in the future.

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INTRODUCTION

Golf is a repetitive sport, associated with large compressive, torsional, and shear loads on the spine and high segmental angular velocities (Smith et al., 2018). Lateralization in golfers occurs due to the highly asymmetrical golf swing. The term dominant or lead side refers to the side closest to the target, while the non-dominant or trail side refers to the furthest side from the target. In right-handed golfers, the left side is dominant side, while the right side is non-dominant side, and vice versa (Bourgain et al., 2022). Lateralization in golf causes the body to activate different main muscles between the right and left sides in each swing movement in golf (McHardy & Pollard, 2005).

The golf swing can place a large load on the spine due to the need for a large range of motion (ROM), especially in the transverse plane, and changes in movement and acceleration as the golfer transitions between swing phases (for example from backswing to downswing) resulting in high joint moments. Activation of the trunk muscles in preparation for hitting the ball and changing the direction of movement can also cause large compressive forces on the spine, especially the lumbar region. Thus, the mechanism of injury and mechanical low back pain (LBP) due to the kinematics and kinetics of the golf swing on the spine is considered quite relevant (Kanwar et al., 2021).

Meanwhile, the large force and ROM during golf activities greatly affect the loading on the hip area, where during the downswing, the hip area is the main fulcrum and experiences a greater rotational speed. Large loading also occurs on the hip joint from the peak of the backswing to the middle of the follow-through due to the high momentum of the extensor, abductor, and internal rotator joints. Someone who has an imbalance in the back and pelvic muscles will be more at risk of experiencing LBP (Kanwar et al., 2021).

The lower back area or lumbar spine has the greatest prevalence of injury in golfers, which is around 55% in professional golfers and 15-35% in amateur golfers. Furthermore, the second highest prevalence is pelvic injuries (19.3%), and the prevalence of injuries to other areas of the body has also increased in recent years (Kanwar et al., 2021). Other research states that back and spinal pain ranks second after upper extremity injuries (Moon & Kim, 2023). Regarding back pain, the highest prevalence of pain when practicing golf is in the lumbar area (37.3%), followed by cervical (8.6%), and thoracic (5%) (Murray et al., 2023).

Thoracic spine injuries are less common due to the increased biomechanical support of the thoracic cavity, including the sternum, ribs, costal cartilages, and associated ligaments. However, it is one of the most feared because it has the potential to cause serious injury (Creighton et al., 2022). The high prevalence of golfers experiencing LBP certainly needs to be prevented so that it does not increase.

A clinical scenario of a man, a 58 years old retiree, a man, 58 years old, who for the last 8 years has regularly played golf once a week, ± 4 hours, with an average of 100 strokes accumulated, 18 holes. The patient comes to a sports clinic to improve his performance while playing golf. Currently the patient has no complaints of LBP or other complaints. However, when the examination was carried out, the patient had variations in posture in the form of a head that was tilted to the right, a higher left shoulder and hip, both shoulders were rounded, with an NYPRS score of 55/100, the forward bending test had a hump on the right upper back, difficulty lateral bending to the left side, and difficulty performing training movements such as: not being able to back extend during the superman; thoracic segment tends not to move up and down on cat and cow movement, the thoracic opener and russian twist are more limited to the right side, single arm rowing is more difficult on the right side, wood chop from the lower left side to the upper right side is limited, thread the needle on the right side is more difficult, the left shoulder press is more difficult, the static bird dog is more unbalanced when the right leg as the stabilizer, and the buttocks are tilted to the right when doing the squat. The patient was then diagnosed with muscle imbalance, T1-T6 thoracic scoliosis (to the left, with a Lippmann Cobb angle of 22^0), and straight cervical. The patient asked whether with the condition found he could still play golf regularly? Are there any golf movements that he needs to pay attention to in order to prevent him from experiencing LBP?

The limited movement of the musculoskeletal system is one of the things that needs to be considered in ensuring safety when doing physical exercise or sports (American College of Sports Medicine, 2021). One measure to prevent LBP that can be taken is to identify the biomechanics of a golfer's golf swing. Based on clinical scenarios, even though golfers currently do not have subjective complaints of LBP, it is suspected that the stages of the golf swing can result in a condition of muscle imbalance, and then the muscle imbalance will affect the swing movement when someone plays golf. In the end, these conditions that continue to rotate, combined with the conditions of variations in posture and muscle imbalances that golfers have previously had, will increase the risk of experiencing LBP in the future.

Therefore, the aim of this paper is to find out whether the stages of the swing movement in golf can indeed increase the risk of LBP through an evidence-based case review with population (P) is adult golf players (> 18 years), amateur or professional; Issue/Intervention and Comparison, namely the various stages of the swing movement in golf; and Outcome is the risk level of LBP. Furthermore, this research also wants to find out to what extent the condition of the golfer found in the case scenario increases the risk of experiencing LBP when making a golf swing. In this way, it is hoped that he can be given more appropriate exercise therapy to reduce his risk of experiencing LBP and he can continue playing golf more safely.

METHOD

This research is an evidence-based case report, with article searches conducted by the author from March 3rd to March 10th, 2024. The findings are displayed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart. The search focused on identifying articles aligned with the PICO framework across Scopus, PubMed, and Cochrane, as well as searches from various other sources via hand searching. Search articles using keywords from PICO and boolean operators (AND, OR) to find the best results. Apart from keywords, searches are also carried out using synonyms as word combinations in search engines.

Table 1. Search Strategy Based on PICO and Its Synonyms

P	I	C	O	S
• *Golf* • *Golfer*	• *Golf Swing* • *Biomechanics* • *Motion* • *Movement* • *Posture*	• *Golf Swing* • *Biomechanics* • *Motion* • *Movement* • *Posture*	• *Muscle Imbalance* • *Low Back Pain* • *Risk Injury* • *Injury*	• *Meta-Analysis* • *Systematic Review* • *Randomized Controlled Trial* • *Case-Control* • *Cohort*

Source: Author

Researchers used Mendeley Desktop to save search results and perform duplication checks on all articles to finally obtain the total number of articles without duplication. After that, the author read the article titles and abstracts one by one to select articles that match the PICO keywords. Then see if the article is accessible, has full text available, and evaluate its suitability to the inclusion/qualification criteria, namely:

1. Articles are written in Indonesian or English;
2. Articles can be accessed in their entirety;
3. Articles published in the last 10 years (2015 – 2024) in Scopus or Sinta accredited journals;
4. Type of population: Patients aged > 18 years, who have been involved in golf for at least the last 1 year, both amateurs and professionals, with or without previous complaints of low back pain (LBP), and no other complications;
5. Types of intervention and comparison/control: Various biomechanical positions during the golf swing;
6. Outcome: Risk level of LBP;
7. Type of study design: Systematic Review with or without Meta-Analysis/ Randomized Controlled Trial/ Case-Control/ Cohort/ Review.

Articles that only discuss golf biomechanics without linking it to the occurrence of LBP either directly or indirectly in the form of its impact on the spine are included in the exclusion criteria.

Articles that meet the inclusion criteria are then subjected to a critical review method based on their appropriate study design. This review will utilize the Systematic Review Critical Appraisal Tools Worksheet (FAITH) from the University of Oxford or the Critical Appraisal Checklist for an Article on Harm or Causation for other study designs. Only articles that have met the valid, important and applicable critical review will be selected as study results. Lastly, the level of evidence is determined using the Oxford Center for Evidence-Based Medicine 2011 Levels of Evidence and recommendations using Grading of Recommendation, Assessment, Development and Evaluation (GRADE).

RESULT AND DISCUSSIONS

Research Result

Based on searches carried out using synonyms related to PICO, we searched three databases—PubMed, Cochrane, and Scopus—and identified 1,786 articles after removing duplicates. We then screened these articles by title and abstract, resulting in the exclusion of 1,759 irrelevant or inappropriate articles, 12 articles for which the complete article was not available, and 3 articles that were not in Indonesian or English, so there were 12 articles that would be read through. completely to assess eligibility. After reading the article in full, 1 article has been included in the selected systematic review, and 2 article did not explain the impact on the spine or lower back pain, so that 9 articles will be included in the review to continue at the critical appraisal stage. After a critical appraisal was carried out, all articles were declared valid, important and applicable with a level of evidence range of 2-5. Based on GRADE, the results obtained have a moderate recommendation level with the results obtained being quite confident in the effects and estimates. The actual results are likely to be close to the estimates made in the study but it is still possible that they are substantially different. Thus, a total of 9 articles were obtained as a result of the study and were reviewed. The complete search results are displayed in the PRISMA Flowchart in figure 1 below.

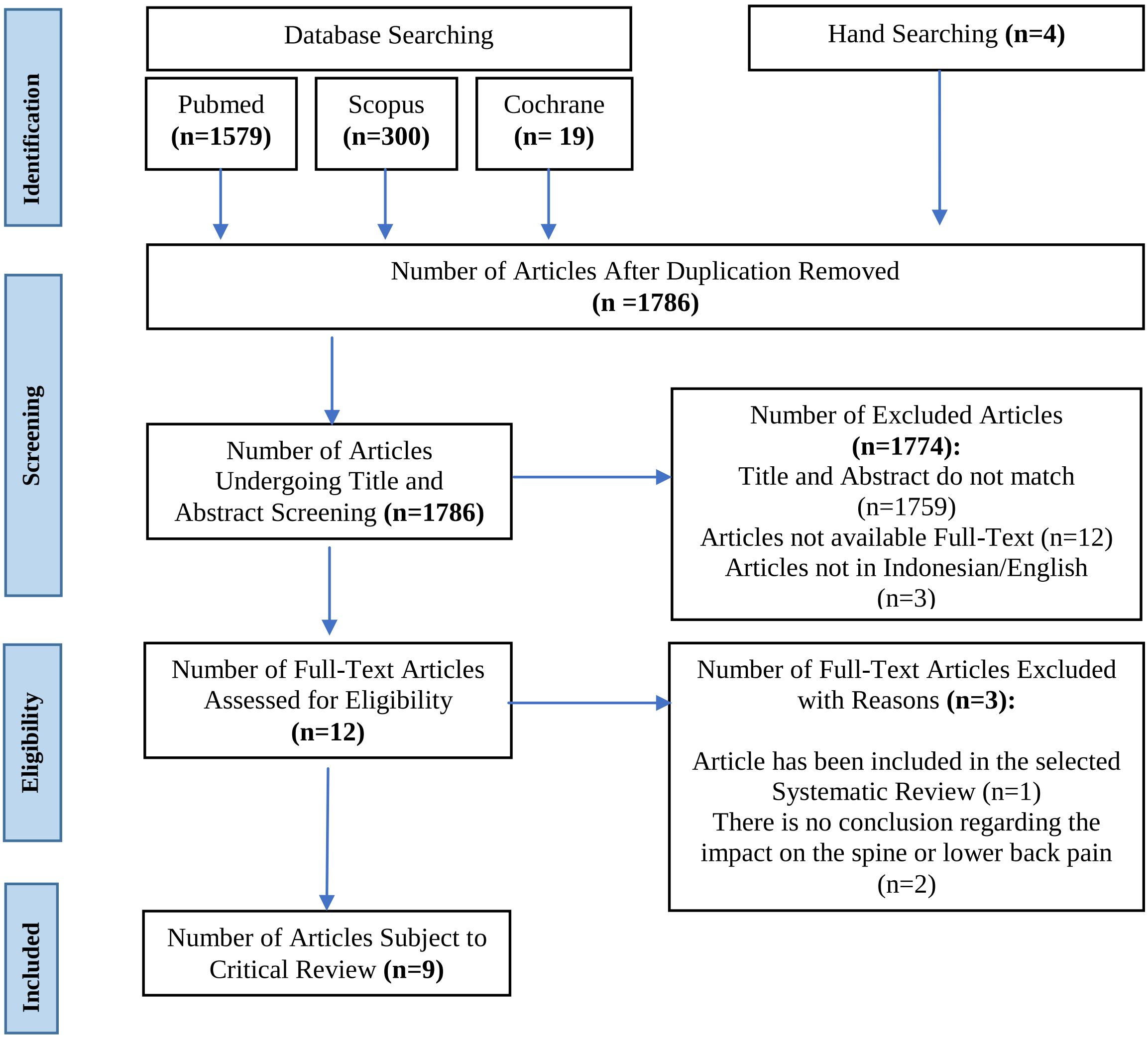

Figure 1. PRISMA Flowchart
Source: Author

The PICO and study characteristics of articles entering the review stage are as follows:

Table 2. Characteristics of Evidence-Based Case Review Results Studies

Researcher (year)	Country	N	Design Study	Characteristic Studies (P)	Intervention dan Comparator (I, C)	*Outcome*
Kanwar K, et al. (2021) (Kanwar et al., 2021)	Los Angeles, USA	15 right-handed (5 women, 10 men), including 2 professional golfers	*Pretest—Post-test observational design.*	1. Professional or amateur golfer, > 18 years old, golf handicap of 24 or less, and has played at least 20 rounds of golf throughout the previous two years. 2. Participant age: 18 - 73 (40.5 ± 16.4) years. 3. Handicap: +2 to −20 (8.6 ± 8). 4. Number of years playing golf: 8 - 50 (23.27 ± 14.18) years.	*Swing Style: Golfer's existing swing vs Minimalist Golf Swing (MGS)*	1. Lumbar spine outcome variables: peak extensors, bidirectional net joint forces at the L4/L5 vertebral level in the transverse (axial rotator) and frontal (lateral flexor) planes; 2. ROM three planes of motion.
Zemková, Erika, et al. (2020) (Zemková et al., 2020)	Country of Origin: Switzerland and Czechia Countries on Review Results: Individual sports: Australia, Belgium, Brazil, Colorado, United Kingdom, Germany, Greece, Italy, Japan, Korea, Poland, Spain, Sweden, Switzerland, and Zimbabwe. Team sports: Norway, Germany, United Kingdom, Sweden and Finland, Switzerland, United States, Australia, Iran and Portugal.	31 research articles for individual athletes → A total of 2,999 athletes with an average age of 26.1 years, consisting of 1,819 male athletes and 1,180 female athletes. 15 studies on elite athletes, 9 on non-elite athletes, and 6 on both elite and non-elite athletes. 17 research articles on team sports → number of athletes in each study was between 29 and 1,110 people.	*Scoping Review*	1. The review was conducted using several databases, including Pubmed, MEDLINE, Web of Science, SCOPUS, CINAHL, and SportDiscus. Additional searches were performed in SpringerLink, Elsevier, EBSCOhost, and Google Scholar, including conference proceedings. 2. Studies involving individual or team sports athletes experiencing back pain and/or injuries, specific training programs, and either objective or subjective measures relevant to this review. 3. Articles that are incomplete (such as abstracts only), not peer-reviewed, lacking original research, or not written in English were excluded from this review.	1. Various things related to training load (especially related to ACWR), including biomechanical, physiological or psychological factors related to stress, and specific exercise patterns. 2. Several factors that affect the location, severity, frequency, and duration of back pain and/or injury in athletes.	The occurrence of back issues among athletes, both individually and as a teams, including pain and/or injury.

Researcher (year)	Country	N	Design Study	Characteristic Studies (P)	Intervention dan Comparator (I, C)	*Outcome*
Bourgain M, et al. (2022) (Bourgain et al., 2022)	Country of Origin: France Country of Review Results: not explained	92 of the 517 articles that had passed the screening process were reviewed	*Systematic Review*	1. Based on Scopus, Pubmed, and IEEEExplore databases. 2. Inclusion criteria: study of golf swing biomechanics; populations of all ages, genders, and golfing skills/proficiencies, whether professional, elite, or recreational; articles published exclusively in English in scientific publications that are indexed; in the time period January 2000 to February 2019 with article searches using title, keywords, and abstract. 3. Exclusion criteria: Articles about other sports (golf only quoted, without specific analysis); Thesis or dissertation; Description and assessment of commercial golf or equipment testing devices; Programs for physical rehabilitation or reconditioning without quantitative information on golf swings; Neurological elements of golf swing; Injury investigations in which biomechanical elements are not discussed; EMG-induced muscle activation; Articles that are only accessible in abstract and not in English; Articles without any results related to kinematics.	Golf swing biomechanics, with a focus on kinematics and how it affects the game.	The role and recommendations of kinematic parameters related to the golf swing: 1. X Factor; 2. Crunch factor; 3. Swing plane and club head trajectory; 4. Kinematic sequence; 5. Kinematics of segmental and joint angles.
Smith JA, et al. (2018) (Smith et al., 2018)	Country of Origin: USA Country of Review Results: Not explained	19 of 101 articles were reviewed	*Systematic Review*	1. Based on the electronic databases CINAHL, PubMed, and SPORTDiscus, without data restrictions, in October 2016 and again in September 2017. 2. Inclusion criteria: Population of amateur and professional golfers across various age groups and skill levels; Written with prospective case-control, cross-sectional, and longitudinal study methods; Studies that assessed practice factors, anthropometric circumstances, biomechanics, or demographic traits in people with and without golf-related LBP were considered peer-reviewed. 3. Exclusion criteria: Articles were case reports, reviews, conference abstracts, treatment studies, or others that included comparisons of individuals with back pain and those without it; The articles referenced were not in English.	Various risk factors are associated with LBP in professional and recreational golfers.	Level of risk of LBP

Researcher (year)	Country	N	Design Study	Characteristic Studies (P)	Intervention dan Comparator (I, C)	*Outcome*
Watson M, et al. (2024) (Watson et al., 2024)	Country of Origin: United Kingdom Country of Review Results: Not explained	9 of 1805 articles were reviewed	*Systematic Review*	1. Based on the databases Embase (1966–present), Web of Science Core Collection (1970–present), Medline (1966–present), Scopus (1960–present), and the Cochrane Central Register of Controlled Trials (1900–present). On February 6, 2021, the literature search was finished, and it was revised on April 7, 2022, and June 6, 2023. 2. Inclusion criteria: All primary studies that present a human biomechanical examination of the golf swing and LBP are eligible to be included; Using the term "lower back" and its synonyms lumbar, lower spine or sacral; Reporting and quantifying pain by any method; All biomechanical measurement domains are considered including kinetic, kinematic and electromyographic techniques; Publications only in English; There are no exceptions regarding demographic characteristics, such as age, golfing ability, significant past medical history and concomitant morbidity; There are no limitations on publication date and research design. 3. Exclusion criteria: Any research that does not investigate pain and motion; Data has not been published.	Several biomechanical factors related to the golf swing have been correlated with the occurrence of LBP.	Level of risk of LBP
Edward N, et al. (2020) (N. Edwards et al., 2020)	Country of Origin: USA Country of Review Results: Not explained	Not explained	*Review*	1. Discuss the specific biomechanics of the golf swing and golfers physical characteristics related to LBP. 2. Risk factors for the golf swing related to LBP, especially regarding the anatomy of the waist and hip. 3. Principles of performing a correct golf swing. 4. Focus on the occurrence of chronic LBP. 5. Based on the SPORTDiscus, PubMed, Medline, and Academic Search Premier databases in August 2018 without date restrictions.	1. Characteristics of swing technique, physical deficiencies, and other biomechanically analyzed variables involved in the development of LBP; 2. Effect of various phases of the golf swing on LBP; 3. Effect of LBP on swing kinematics and muscle activation.	1. Impact of each golf swing on LBP; 2. Decreased frequency of LBP in golfers.
Cole MH & Grimshaw PN (2015) (Cole &	Country of Origin: Australia Country of Review Results: Not	Not explained	*Review*	1. Discussion of the mechanical and neuromuscular aspects associated with the golf swing and the mechanisms of LBP development as an effect of this activity.	Modern vs classic golf swing biomechanics	Impact on low back pain (LBP)

Researcher (year)	Country	N	Design Study	Characteristic Studies (P)	Intervention dan Comparator (I, C)	*Outcome*
Grimshaw, 2015)	explained			2. Discussion of the muscles involved and recruited in this activity.		
Edwards NA, et al. (2023) (N. A. Edwards et al., 2023)	USA	12 previously recorded right-handed male golfers LBP while playing golf and 12 right-handed male golfers without LBP symptoms (NLBP)	*Case-Control Study*	1. All participants have a handicap < 21. 2. Golf experience: more than 12 months. 3. Have not had a neuromuscular injury for at least 6 months that could affect the golf swing. 4. Sign the informed consent document before participating, and complete the modified Oswestry Low Back Pain Disability Questionnaire.	Measure the differences in trunk extension, lateral flexion of the trunk, pelvic tilt, crunch factor, and the sequential movement of trunk segments during the golf swing phase. Additionally, it examines the lower extremity strength of amateur golfers with and without a history of LBP.	Characteristics of golf swing positions that are contraindicated/expected to cause LBP in golfers.
Dalle RB & Brumit J (2016) (Dale & Brumitt, 2016)	USA	13 participants from the University of South Alabama, USA and the University of Tennessee at Chattanooga, USA.	*Experimental Study: Controlled laboratory study*	1. Participants are 38.8 ± 4.2 years old, 1.8 ± 0.1 m tall, 83.6 ± 3.0 kg in weight, and has 16.0 ± 1.4 years of experience. According to the United States Golf Association (USGA) handicap (mean ± SEM), their skill level is 7.1 ± 0.8 strokes. 2. Participants must have no history of injury or surgery within the past year. 3. Participants must have a USGA handicap of ten or less and have engaged in golf for a minimum of three years.	Measuring several kinetic, kinematic, and performance factors to compare skilled golfers' full and short swings.	The idea and impact of the golf swing modification on the golf performance and human spine.

Source: Author

Table 3. Study Results Based on Swing Movement in Golf and the Risks

Researcher (year)	Result
Kanwar K, et al. (2021) (Kanwar et al., 2021)	1. There is a significant difference in ROM between the current swing and MGS when performing maximum and minimum peak movements. 2. MGS a. Significantly reduced lumbar spine axial rotation ROM Significantly decreased axial rotation ROM in the lumbar spine b. (p = 0.008) during downswing, primarily due to right axial reduction away from the rotational motion target. b. Moderate effects include reduction in lateral flexion ROM, and low to moderate impacts on extension and flexion.
Zemková, Erika, et al. (2020) (Zemková et	Two articles were found that discussed golf and LBP which were divided into 2 groups, the LBP group (golfers with a history of LBP or those who still had LBP complaints in the last 12 months to 2 years, experienced 2 or more episodes of LBP triggered by golf with the last episode being felt in the last 6 months) and the control group (no history of LBP and not currently experiencing LBP). The research results show:

Researcher (year)	Result
al., 2020)	1. There is a weak and significant correlation between LBP and hip rotation; and 2. There was a decrease in the lead hip internal rotation ROM in the LBP group compared to the group without pain when lying down and standing.
Bourgain M, et al. (2022) (Bourgain et al., 2022)	1. X-Factor a. Increased X factor is thought to be caused by increased shoulder/pelvis dissociation, which increases the axial rotation of the trunk and shoulder girdle, thereby increasing the elastic potential energy of the trunk muscles. Golfers who start their downswing by rotating their hips will have a higher X factor; b. Practicing for 100 swings session will increase and stretch the X factor; c. For golfers with LBP, partial swings that decrease the backswing amplitude can lessen the compression pressure on the lumbar spine. 2. Crunch Factor a. The crunch factor has no correlation with low back injury risk; b. The crunch factor can be used to investigate LBP occurrence. However, until now, there has been no research that shows a relationship between the crunch factor and LBP. 3. Swing Plane, Clubhead Trajectory, and Kinematic sequence, there is no direct connection between this and the incidence of LBP; 4. Kinematics of segmental and joint angles a. Less mobility in the lead hip is associated with higher use of the lumbar spine; b. In the modern swing, the need for greater axial rotation of the trunk is frequently linked to an increased risk of lumbar spine injury.
Smith JA, et al. (2018) (Smith et al., 2018)	1. Golf swing movement characteristics a. Peak crunch factor showed no significant difference between individuals with and without LBP; b. 2 studies presented no association between golfers' ES lead side onset time in relation to the backswing start and LBP (SMD, –1.33; 95% CI, –4.83 to 2.18; I2, 95.82); c. Bilateral upper and lower lumbar erector spinae (ES) contraction onset was earlier than backswing onset in the LBP group (d range, 0.7–1.0); d. Trend differences between high and low handicap golfers in ES amplitude measurements and external oblique (EO) activity in relation to those with and without LBP. Another report reported abdominal muscle activity did not differ across groups in professional golfers; e. Individuals with LBP showed the most significant biceps femoris activity during the backswing. 2. Strength/flexibility characteristics a. In young professional golfers, the development of LBP during a ten-month period was not predicted by trunk flexor and extensor endurance, peak trunk extensor strength, or side-bridge endurance; b. LBP development was highly impacted by side-to-side asymmetry in side-bridge endurance (r = 0.6), with a variability range of 36%; c. 2 of 3 studies examining active trunk movements in all other planes showed no association between trunk ROM and LBP; d. No association between ROM and LBP based on lead internal rotation and trail hip (lead limb: SMD, 1.25; 95% CI, –1.3 to 3.8); e. External rotation lead and trail hip were not linked to LBP (hindlimb: SMD, 0.1; 95% CI, –0.9 to 1.1; I2, 72.8%; forelimb: SMD, 0.1; 95% CI, 0.7 to 0.9; I2, 61.3%); f. 2 research has revealed that hip internal rotation in individuals with LBP shows more side-to-side asymmetry. 3. Other factors that increase the risk of LBP a. Age: Older age is significantly linked to LBP (SMD, 0.57; 95% CI, 0.07 to 1.07; I2, 79.9%); b. Gender: Men are more likely to experience pain (OR, 3.4; 95% CI, 1.3 to 13.4); c. Novice recreational golfers: history of previous back pain is a strong predictor of future LBP over the next 12 months (Relative Risk (RR), 9.8; 95% CI, 4.5 to 21.4); d. Body Mass: Higher body mass is significantly associated with LBP (SMD, 0.36; 95% CI, 0.09 to 0.63; I2, 0.0%). Golfers with LBP have a heavier body mass; e. Body Mass Index (BMI): In professional golfers, BMI is negatively correlated with LBP symptoms frequency (% of time) over a 10-month period (r = −0.7); f. Exercise: Exercising less than 1 hour per week is linked to a lower LBP risk (OR, 0.5; 95% CI, 0.3 to 0.8); g. Play Frequency: More rounds and shots each week are associated with Increased spinal pain; h. Handicap: No association exists between handicap and LBP (SMD, 0.0; 95% CI, –0.3 to 0.4; I2, 0.0%).

Researcher (year)	Result
Watson M, et al. (2024) (Watson et al., 2024)	1. The majority of reported outcomes did not differ significantly between the LBP group and the control group a. There is heterogeneity of results. Variables associated with LBP are not supported by other studies; b. There were no significant differences in peak lumbar flexion, extension or rotation; lumbar extension or rotation velocity; hip angle, trunk angle and crunch factor or trunk extension; trunk movement speed and the incidence of LBP; and ES activity at the start of the backswing between elite golfers with and without LBP. 2. Golfers with LBP show greater upper thoracic lateral flexion; greater knee abduction; peak lumbar lateral flexion lead side, and greater start of backswing; reduced knee flexion (lead); reduced ankle dorsiflexion; greater trail hip abduction; reduced knee adduction (lead); increased adduction of the ankle (lead); increased knee flexion; increased trail hip adduction; reduces lead eversion of the ankle; reduced knee (lead) flexion, and reduced ankle lead dorsiflexion, replicated at more than one point of the swing; 3. In elite golfers with LBP a. Demonstrated greater peak lateral flexion velocities, whereas golfer without LBP had greater peak lumbar flexion velocities; b. Generate significantly lower torque during the transition phase of the golf swing; c. Show a significantly shorter transition phase than those without LBP. No significant differences were reported when the transition phase was determined by hand speed (lead); d. Show increased base activity of the rectus abdominis (RA) and latissimus dorsi (LD) on the trail side at the end of the backswing, at impact, and greater average activity of both muscles throughout the swing; e. Have increased activation of the RA lead (7-10% more active, (effect size = 0.29 – 0.91)) and LD lead (2-8% more active, (effect size = 0.24 - 0.27)) at various points in time during the swing compared to golfers without LBP; f. Experience EO contraction at the start of the backswing, but this does not occur among recreational golfers; g. The mean amplitude of EO activation during the swing did not differ significantly between elite golfers with and without LBP; h. There is no significant difference in mean EO activity in elite golfers with and without LBP; i. Mean amplitude of RA and internal oblique (IO) activity throughout the swing did not differ significantly in elite golfers with and without LBP; j. IO contraction times at the start of the backswing and the start of the downswing among elite golfers with LBP were not significantly different from those without LBP; k. There are no differences in other basic muscle activity and training between elite golfers with and without LBP; l. Demonstrate greater lumbar lateral flexion at the start of the backswing. In contrast, other studies report no differences in recreational golfers; m. LBP that is felt has an average duration of the first episode of 2-3 weeks, an average duration of the second episode of 2-3 weeks, there are also those who feel LBP and leg pain simultaneously, or LBP alone without leg pain, and even when there is LBP there is keep playing golf; n. The group of elite golfers without LBP had higher body mass and body mass index (BMI); o. There were no differences in age, height, smoking history, past medical history, and previous history of LBP; 4. In recreational golfers a. Golfers with high handicaps and LBP exhibited greater ES activity at the end of the backswing compared to those without LBP; b. Higher handicap golfers showed no difference in ES activity, lower handicap golfers with LBP demonstrated reduced ES activity compared to those without LBP; c. Earlier activation of the lumbar ES was noted at the start of the backswing in golfers with LBP, but no differences were found at the end of the backswing or start of the downswing; d. LBP golfers had greater bilateral ES activity at the end of the backswing, with no significant differences observed in ES activity during the swing; e. LBP golfers had no differences in EO activity at the start of the backswing or at impact but showed increased EO activity at the end of the backswing; f. The injured group shows more activity in the trail-side EO at the end of the backswing; g. Neither group showed significant differences in onset of EO at the start of decline; h. No difference in EO onset impact, and anterior RA and LD activity between golfers with and without LBP; i. There was no significant difference in lumbar torque produced by LBP or non-LBP recreational golfers from backswing initiation to impact;

Researcher (year)	Result
	j. Recreational golfers with and without LBP did not significantly differ in the torsional loads they produced during the transition phase, though they did generate fewer torsional loads than elite golfers; 5. EO activity on the trailside did not significantly differ between elite and recreational golfers with LBP in comparison to those without LBP; 6. There was no significant difference in peak rotational velocity of the lumbar spine between golfers with and without LBP, in the recreational group and the mixed group of elite and sub-elite golfers, respectively.
Edward N, et al. (2020) (N. Edwards et al., 2020)	1. Risk factors findings • Playing with higher frequency → increased risk of overuse injuries. It further increases when the golfer displays poor technique. 2. Spinal strength and muscle activation a. The combination of paraspinal muscle activity and GRF affects the lumbar spine during the golf swing; b. Patients with LBP have 26.3% and 75.5% greater lateral compression and shear forces compared to healthy individuals during bending and lifting. This may be due to the fact that in LBP patients have greater anterior and posterior muscle coactivation; 3. Golfers with LBP a. Reduced trunk flexion during the downswing, and overall trunk ROM due to lack of abdominal muscular activity during the swinging motion; b. Lack of ES muscle action during the swinging motion; c. Activating the ES prior to the start of the backswing significantly earlier than golfers without LBP; d. Reduced multifidus activity; 4. Exercise can help address muscle strength and endurance deficits and LBP management related to pelvic stabilization; 5. Increasing ROM, strengthening the hip and trunk muscles, and changing the way of swing can reduce LBP complaints. 6. Crunch Factor a. In a golf swing, the downswing, impact, and start of the follow-through are when the axial rotation and lateral bending peak values are most noticeable. The research' findings on the relationship between the 'crunch factor' and injury risk are inconsistent; b. The statement that the 'crunch factor' is a risk factor for LBP does not have sufficient evidence to support it; c. No significant difference between golfers with LBP and those without symptoms when assessed with a lumbar movement monitor or through 3-D movement analysis. 7. Excessive rotation: a. Golfers with LBP have dynamic ROM in their swing that exceeds the limitations of their passive ROM, especially in trunk rotation. An attempt to enhance the separation between the pelvis and trunk may be indicated by excessive trunk rotation; however, moving beyond active ROM can negatively affect spinal health; b. During movement, both golfers and non-golfers with LBP typically show decreased trunk flexion; c. Decreased trunk flexion is associated with a decline in trunk and pelvic rotation, which may lead to increased forces on the lumbar spine; d. Compared to a full swing, a shorter backswing that restricts trunk rotation has been shown to reduce spinal load; e. Tests on shortened golf swings have shown no significant improvement in clubhead speed or shot accuracy; f. Utilizing a shorter golf swing might be a strategy to limit excessive rotation while only minimally affecting performance. 8. Potential risk factors a. Lack of weight transfer to the back of the leg during the backswing can be caused by a forward tilt of the pelvis, which causes strain on the golfer's spine and hips and reduces the golfer's ability to execute the downswing in the correct sequence; b. A forward pelvic tilt during the backswing can hinder weight transfer to the back leg, putting strain on the golfer's hips and spine and making it harder for golfer to perform the downswing in the proper order; c. During the backswing, professional golfers with LBP have demonstrated increased front side lateral bending. 9. Lumbar hyperextension

Researcher (year)	Result
	a. Lumbar hyperextension decreases trunk rotation ROM by 4.2% and increases hip ROM by 4%. In contrast, 22.5^0 lumbar flexion decreases trunk rotation ROM by 5% and hip ROM by 17% compared to a neutral spinal posture. b. When compared to a neutral spinal posture, lumbar hyperextension reduces trunk rotation range of motion by 4.2% and increases hip range of motion by 4%, whereas 22.50 lumbar flexion reduces trunk rotation range of motion by 5% and hip range of motion by 17%; c. Paraspinal muscles stabilize the spine by compressing the vertebrae in poor lumbar curves, which may reduce ROM; d. No differences variations in the activation of the abdominal muscles were reported between healthy golfers and golfers with LBP. 10. Improper pelvic alignment a. The distribution of force on the spine during the swing is impacted by variations in spinal posture. This pelvic motions series is caused by the correct pattern of muscle activation for PDS during the swing. A posterior pelvic tilt can result from the lumbar vertebrae and activation of the anterior truncus muscle flexing during the downswing; b. Proper muscular activation patterns and adequate ROM between the muscles that control the pelvis (such as the IO, EO, ES, Gluteus Maximus (GMx), and Gluteus Medius (GMe)) are necessary for the interaction between the pelvis and lumbar spine; c. When the spine is moderately kyphotic, pelvic rotation is at its maximum, and when it is hyperextended, it is at its smallest. Golfers who have suboptimal trunk or pelvic alignment may be more susceptible to LBP because of restricted rotational ROM.
Cole MH & Grimshaw PN (2015) (Cole & Grimshaw, 2015)	1. Injured golfers do not show significant differences in address position, trunk flexion angle, or lateral flexion toward the trail side compared to uninjured golfers; 2. Injured golfers exhibit greater lateral flexion and less trunk rotation towards the trail side during the backswing, with a wider ROM than in the swing; 3. Golfers with LBP achieve similar trunk extension, right-sided lateral bending, and axial trunk rotation velocities as asymptomatic golfers; 4. Golfers with LBP have higher lateral flexion and trunk flexion velocities towards the front side; 5. Right-sided trunk rotation and lateral flexion angles peak and velocity towards the front side during the backswing are generally considered low risk. 6. Crunch factor a. Lateral trunk flexion toward the trail side and peak axial trunk rotation after ball impact may contribute to lumbar spine degenerative changes and injuries; b. The crunch factor could objectively measure trunk mechanics in golfers, with peak values around 52 ms post-impact linked to spinal cord injury risk; c. Other studies indicate that golfers with LBP have similar peak crunch factor scores as asymptomatic golfers, suggesting other factors may lead to lumbar injuries. 7. Joint mobility and flexibility a. Golfers with LBP have no different joint mobility than golfers without LBP symptoms; b. Some research and personal stories suggest that limited movement in the hips or spine may lead to LBP symptoms. c. Golfers with LBP have a limited ability to rotate their primary hip inward and outward (to the left for right-handed golfers) during the swing; d. According to some limited data, golfers who suffer from long-term LBP have less flexible spines, which significantly impairs their capacity to bend and rotate their upper bodies. e. Although individuals with LBP can correctly perform a variety of clinical tasks related to specific movement criteria, golfers with LBP use different muscle recruitment strategies to achieve these results. 8. Muscle strength a. In acute and chronic LBP disease, the function of the transverse abdominis and lumbar multifidus muscles is more impaired than the superficial function; b. After 3 months of resistance training and conditioning, lumbar ES activity was reduced during the downswing phase; c. Experienced golfers with LBP had significantly lower ES activity levels but higher EO activation compared to asymptomatic controls; d. The ratio of EO to ES activity at impact was almost 2.5 times higher in low-handicap LBP golfers than asymptomatic controls; e. Given the high joint loading, decreased ES activity may indicate neuromuscular weakness in failing to sufficiently stabilise the spine following impact. Conversely, it may also be linked to lower compressive forces and a lower risk of injury;

Researcher (year)	Result
	f. The amplitudes of RA, EO, and IO activity did not differ significantly between symptomatic and asymptomatic players; g. Golfers with LBP activate their lumbar ES in preparation for the backswing significantly earlier than asymptomatic players; h. In individuals with LBP, earlier activation of superficial ES indicates that these muscles are more important for spine stabilisation; i. Trunk muscles strength and endurance are reduced in golfers with LBP; j. Golfers with LBP showed delayed activation of the primary EO (left side in right-handed golfers) during the backswing compared to asymptomatic controls. k. In patients with LBP, the delayed onset may indicate compromised feedforward control techniques; l. In order to maintain spinal stability during dynamic tasks, decreased function of trunk muscles like RA and ES may necessitate greater activation of synergies; m. Function of deep trunk muscles does not recover spontaneously after pain symptoms subside; n. Golfers' LBP symptoms may be lessened by strengthening and controlling trunk muscles.
Edwards NA, et al. (2023) (N. A. Edwards et al., 2023)	1. Independent t-test results a. Age (LBP = 35.1 ± 13.8 years, NLBP = 34.4 ± 15.7 years, p = 0.913), golfing experience (LBP = 16.8 ± 12.5 years, NLBP = 19.1 ± 11.3 years; p = 0.636), handicap (LBP = 8.0 ± 6.8, NLBP = 11.2 ± 7.1, p = 0.267), BMI (LBP = 28.5 ± 5.2 kg/m2, NLBP = 27.4 ± 4.2 kg/m2; p = 0.574), and maximum club head speed (LBP = 2.42 m/s, NLBP = 38.6 ± 2.67 m/s, p = 0.785) did not significantly differ among the groups; b. The peak angle of velocity magnitude differed significantly between the segments of the pelvis, upper trunk (UT), and lower trunk (LT); c. The modified Oswestry LBP Disability Questionnaire score for the LBP group = 10.5% ± 8.9%, indicating a minimal degree of disability. 2. MANOVA Analysis a. There were no notable variations in sequence pattern (p = 0.643, partial η2= 0.20), lower limb strength (p = 0.828, partial η2= 0.23), or swing kinematics (p = 0.693, partial η2= 0.23); b. Regardless of group, peak pelvis angular velocity (95.2 ms ± 21.4 ms pre-impact) and LT (90.2 ms ± 19.1 ms pre-impact) occurred significantly earlier than peak angular velocity of the UT segment (80.3 ms ± 12.7 ms before impact) for both groups (p < 0.001, d = 0.889, and p = 0.003, d = 0.669, respectively), however no significant differences were found between the timings of maximum angular velocity of the pelvic segment and LT (p = 0.182; d = 0.281); c. There were no significant differences between groups in the crunch factor, muscle strength, trunk extension, trunk lateral tilt, or pelvic tilt; d. Regression analysis revealed that trail hip extension and abduction strength significantly predicted peak hip angular velocity during the golf swing, specifically for those golfers who had previously suffered from LBP (p < 0.001); e. Instead of increasing velocity in a proximal-to-distal sequence, the LT helps the pelvis transfer velocity to the upper body; f. In order to produce angular velocity during the golf swing, amateur players with a history of LBP might exhibit a greater reliance on hip strength.
Dalle RB & Brumit J (2016) (Dale & Brumitt, 2016)	1. 2D backswing analysis shows that for short swings, the average backswing club angle is 231 ± 2° and for full swings, it is 265 ± 3° (p < 0.001, Cohen's D > 0.8); 2. Backswing reduction and X factor each had large and medium effect sizes on performance; 3. Kinetic data analysis indicates that the peak force Fc was significantly reduced in the modified short golf swing (p < 0.05), with a Cohen's D of 0.37, reflecting medium effect. However, the other forces, Fls and Fap, showed no significant differences (p > 0.05); 4. A shortened backswing greatly decreases the X-factor by 4° in 3D and approximately about 34° in 2D, resulting in a significant decrease in CHV and shot distance.

Source: Author

Discussions

The rotational biomechanics of the golf swing have been identified as an important factor in injury prevention (Olshock, 2019). The golf swing is said to produce large compression, displacement, lateral bending and rotation loads on the spine (especially the lumbar) and back, i.e. representing a force equivalent to approximately 8 times body weight. In addition, the asymmetric movement speed of the trunk, which during backswing phase is slower than downswing and follow-through phase, causes the distribution of pressure exerted on the back during the golf swing to become asymmetrical (Zouzias et al., 2018), thereby increasing risks to the spine and back, one of which is LBP. Based on evidence-based articles found, there are not only mutually reinforcing results but also conflicting results between one study and another. Swing skill technique, and other conditions such as age, gender, body mass, BMI, history of disease, level of physical fitness are also variations that can differentiate the risk of LBP between one golfer and another.

Based on examination of clinical scenarios, variations in posture and compensatory mechanisms occur in patients from head to toe continuously. Theoretically, the condition of scoliosis will result in tissue shortening on the concave side accompanied by shortening of the intervertebral joint capsule, causing facet joints compression. In addition, the intervertebral muscles, including erector spinae, quadratus lumborum, psoas major and minor, and oblique abdominis, shorten on the concave side of the spine. The anterior and posterior longitudinal ligaments, ligamentum flavum, and interspinous ligaments also shorten on the concave side, which restricts flexion toward the convex side. This makes it more difficult for patients to bend laterally to the left side. Lateral movement of the spine generally tends to cause spinal imbalance (Fadzan & Bettany-Saltikov, 2018). Apart from that, movement of the spine to the left will cause the area on the right side to be more hyperactive and the area on the left side to be more hypoactive.

The patient also saw several other limitations when exercising. These findings mean that the patient may experience hyperactivity in the bilateral levator scapula, bilateral upper trapezius, bilateral pectoralis major and minor, bilateral sternocleidomastoid, bilateral subscapularis, bilateral teres major, bilateral latissimus dorsi, bilateral erector spinae, tensor fascia lata especially on the left side, gluteus maximus especially on the right side, quadratus lumborum especially on the right side, bilateral hip flexor, and quadriceps especially on the right side. On the other hand, the patient also experienced hypoactivity in the middle/lower trapezius bilateral, serratus anterior bilateral, rhomboid bilateral, infraspinatus especially on the right side, teres minor especially on the right side, quadratus lumborum especially on the left side, multifidus, rectus abdominis bilateral, external obliques especially on the left side, internal obliques especially right side, and gluteus medius bilateral.

Several findings in this case scenario are also included in the points that can increase the risk of LBP in golfers, such as decreased trunk muscle strength and/or endurance, limited mobility of the hips and/or spine, decreased flexibility of the spine thereby limiting the trunk ability to rotate and flex, bending of the right side of the lumbar increases in the impact and follow-through, reduced multifidus activity, more active LD, left and right hip rotator (external rotator/internal rotator) muscle imbalance, and possibly an increase in the crunch factor. This condition is thought to result in the torso being in a more upright address position; in the backswing, the trail side of the shoulder and back may experience increased external rotation, and conversely, the lead side has more internal rotation, resulting in greater lower back rotation, while lateral flexion, especially the lead side, is more limited. Torso flexion will appear to be reduced during the downswing. The limited flexion on the left side causes the patient to appear more limited when performing flexion movements on the lead side during follow-through.

In a study involving golfers without LBP symptoms but with more limited hip ROM (<20°), significantly lower right hip external rotator and left hip internal rotator strengths, less right hamstring flexibility, and increased right hip flexion angle were demonstrated compared to those with normal hip ROM (≥30°) (Kim et al., 2015). If the vertebrae remain parallel to each other during the swing, the pressure generated is not as much as when some of the disc space narrows during rotation due to impact. In addition, reducing crunch during the downswing, increasing hip rotation, standing straighter, and other swing changes are also recommended to prevent and/or reduce the occurrence of back pain (Olshock, 2019). This is reinforced by findings from other studies which state that increasing hip rotation ROM, especially lead hip internal rotation ROM (Zouzias et al., 2018), can help coordinate joints between the lumbar spine and lead hip joints (Mun et al., 2015), and be considered as an important part of an exercise program to prevent the occurrence of LBP (Zouzias et al., 2018). Other things that are said to reduce the occurrence of LBP when performing a golf swing are:

1. Optimize rotation by increasing the trunk flexion angle from 0^0 to 45^0 with a neutral spinal posture (hip rotation ROM will be maximum at trunk flexion with an angle of 0°) (N. Edwards et al., 2020);
2. Perform MGS by reducing hip flexion and abduction during the backswing (Kanwar et al., 2021);
3. A shorter backswing with reduced body rotation is reported to reduce spinal load compared to a full golf swing (Dale & Brumitt, 2016; N. Edwards et al., 2020);
4. Elevate the front heel during the backswing and stand closer to the ball to reduce spine flexion and rotation;
5. Doing trunk muscle strengthening and control exercises, thoracic spine (mid back) extension exercises, such as RA and ES, muscles involved in pelvic stabilization, and increasing ROM can overcome muscle strength and endurance deficits and help relieve LBP symptoms in golfers (Quinn et al., 2022);

6. Do core strength, balance and hamstring flexibility exercises (Creighton et al., 2022).

Based on this, although there are still many differences of opinion regarding whether certain golf swing movements can cause LBP, maintaining spinal alignment, one of which is by shortening the backswing and doing points 1-6 as listed above, can be considered for athletes and coaches who have athletes with LBP or a history of LBP. Meanwhile, for healthy athletes, a full golf swing is said to support performance, especially in terms of CHV and shot distance. Providing training for golf athletes should be designed to activate and mobilize the muscles of the scapula, trunk, and pelvis that focus on increasing flexibility in the large muscles in the lower back and hips, as well as overcoming muscle asymmetry due to repeated golf swings.

All instruction must be tailored to the individual, especially considering age, physical fitness, handicap, ability to perform swing technique, golfer's flexibility, and history of previous injuries (Olshock, 2019). The strength of this study is that it can explain golf swing biomechanics impact on the incidence of LBP accompanied by case scenarios so that it can show clinical implications that can be applied if similar cases are found. However, this study still included review articles with a level of evidence of 5 and several studies that showed different results, thus there is still the possibility of producing different impacts on each golfer. Therefore, further research with better study designs is still needed.

CONCLUSSION

Evidence-Based Case Report from 3 databases (Pubmed, Scopus, and Cochrane) and hand searching found 9 articles: 1 pretest-posttest observational design, 2 reviews, 1 scoping review, 3 systematic reviews, 1 case-control, 1 experimental studies: controlled laboratory studies. Flexion speed, length of transition phase, onset time and strength of muscle contractions, such as ES, EO, LD, X factor, crunch factor, swing plane and clubhead trajectories, and sequences and angles kinematics during the swing can potentially influence the risk of LBP. The conditions of variations in posture and muscle imbalance in the case scenario will further increase the risk of LBP. For coaches or athletes with LBP or a history of LBP, shortening the backswing may be considered to maintain spinal alignment. For healthy athletes, the golf swing can still be performed to its full potential. However, there are still differences of opinion between each study and the quality of the evidence is limited. There is no conclusive evidence to support the belief that golf swing biomechanical factors are strongly related to LBP. There is a need for further research related to this with better study designs in the future.

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