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Roles of Golf Biomechanics on Golfer Performance: An Evidence-Based Case Report

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ABSTRACT

Classic and modern swings are movements that are often performed when playing golf with the main difference laid in the position of torso and pelvis. In addition to the swing pattern which already has its own advantages and disadvantages, the same type of swing movement in reality is likely to be executed differently by one golfer to another. The differences in golf swings, biomechanically from address to follow-through, aims to affect the level of performance of a golfer. However, it is necessary to find out biomechanical positions and conditions that have significant influence on golf performance when performing golf swings and shot. This study aimed to determine how the biomechanics of golf swings influence the performance of adult golfers through an evidence-based case report. The search of articles applied a number of inclusion criteria. The articles were searched from Pubmed, Cochrane, Scopus, and manual searches. The result was displayed in the PRISMA Flowchart. Based on the search results, 15 articles were found and met the eligibility criteria. The articles included 1 Systematic Review, 5 experimental studies, and 9 cohorts. The articles show that the angle between thorax and pelvis and the ability to control spinal movement will change the X-factor, while the X-factor stretch affects performance. Weight transfer location, grip position, gender differences, golf functional movement, and skill level also determine performance. X-factor, X-factor stretch, crunch factor, including grip position, and stance are components that can differentiate golfer performance. Understanding the biomechanics factors of an individually-tailored golf swing can help optimize a golfer performance. Further research is expected to include Indonesian golfers, with various handicap levels for the subject criteria, by using various designs, such as RCTs and cohort studies.

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INTRODUCTION

The development of golf in Indonesia may not be as massive as in other sports. However, currently, Indonesia has succeeded in having more than 150 golf courses (Indonesia Impression DMC, 2025) and golf has even become a promotional attraction for local and international tourists (Yuliana, F., & Barlian, 2023). At the level of competitive sports, the number of professional golfers in Indonesia is also increasing (Professional Golf Association Indonesia, 2022) and several golf tournaments have also been successfully held in Indonesia (Yuliana, F., & Barlian, 2023). For this reason, a study on how to improve the performance of a golfer should be considered so that Indonesian golfers can compete to achieve optimal performance.

A person performance in playing golf can be influenced by various factors, such as anthropometry and the fitness level of the golfer (Evans & Tuttle, 2015; Wells et al., 2009), the absolute volume and bilateral asymmetry of certain trunk muscles (Izumoto, Kurihara, Maeo, et al., 2020; Son et al., 2018), the golfer skill level (McHugh et al., 2024), and the characteristics of the bat, both irons and drivers (Brožka et al., 2022; Yang et al., 2024). Another important factor is how the golfer can biomechanically execute the swing movement well from the address, backswing, to follow-through phases. A poor swing execution, instead of improving performance, could actually cause an injury (Cabri et al., 2009; Cole & Grimshaw, 2015; Creighton et al., 2022; Lindsay & Vandervoort, 2014; Paramita & Sutarina, 2024).

The swing movements in golf that are widely performed consist of at least 2 types, namely classic and modern swings (Cole & Grimshaw, 2015). However, these two swing movements may actually be different when performed by one golfer with another. In every swing and hitting movement, a golfer requires a good level of attention and motor control and they are not exactly the same. These swing movements sometimes still have subtle differences so that there are rarely anything "black" or "white" (Carson et al., 2014). The unique way of each golfer in executing a series of golf swings is perceived to have an influence on their performance level.

To study the execution of the golf swing, the researcher who also provided services at an Exercise Center in Jakarta intended to raise a clinical scenario that had been approved by one of the recreational golfer patients who came to improve his golf performance. The patient was a 58-year-old man who had been playing golf for a hobby for 8 years. He played golf once a week for + 4 hours, with an average accumulation of 100 strokes per practice session, and the ball fell in the yellow to white area (+ 150 – 200 yards). The patient also said that he was a 25 handicap, 18 holes. The patient came to a sports clinic to improve his performance in playing golf. After an examination, researcher as the doctor of this patient found a variation in posture with an NYPRS score of 55/100 and a more hyperactive right side area. We also asked him to demonstrate the golf swing movement that the patient usually did. It was apparent that the trunk position was more upright and the knees were less flexed, especially the right knee (trail), from the address to the end of the downswing. At the beginning of the backswing, lateral flexion of the left side of the trunk (lead) appeared limited. On the other hand, twisting movements appeared to occur more in the hips, where lead hip internally rotated and trail hip externally rotated. Meanwhile, the shoulders and upper back rotated along with the rotation of the hips, with rotation of the upper back (thoracic segment) appearing more limited than the lower back (lumbar segment). Trunk flexion reduced during the downswing. At the time of impact and the beginning of the follow-through, lateral flexion of the trunk on the trail side and axial rotation of the trunk towards the pelvis (lead side)

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began to be more visible, accompanied by internal rotation of the lead hip and knees that were more flexed, especially on the trail side. The limited flexion on the left side caused the patient to be more limited when performing flexion movements on the lead side during the follow-through phase. Based on the results of this examination, we suspected that the biomechanical condition of the patient golf swing was one of the aspects that could affect his performance.

To help the patient improve their golf performance, the researcher as his doctor aimed to find out through an evidence-based case report about the appropriate biomechanics of body movement positions (such as limb positions, stance, club grip, club swing, and ball hit) when performing golf swing and stroke movements to significantly improve golf performance. Therefore, the purpose of this study was to find out how the biomechanics of the golf swing influence the performance of adult golfers through an evidence-based case report. The problem formulation included the kind of swing and hitting movements that could improve the performance of adult golfers.

Unfortunately, amidst the development of golf in Indonesia, the research in Indonesia discussing golf is still limited, especially about the biomechanics of the golf swing related to performance both in competitive and recreational terms. The results of this evidence-based case report are expected to be the initial foundation for both recreational and elite golfers, as well as for coaches in creating golf training programs. Therefore, they can improve their ability to play golf and reduce the risk of injury.

METHODS

The search for articles in this case report was carried out from June 14th, 2024 to June 18th, 2024 and was displayed in the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Flowchart chart. The search was carried out to find articles relevant to the PICO in three online databases, namely Pubmed, Cochrane, and Scopus. Searches from various other sources via hand searching was also carried out. The search of articles used keywords from PICO and boolean operators (AND, OR) to find the best results. Apart from keywords, searches were also carried out by using synonyms as word combinations in search engines. Medical Subject Headings (MeSH) on Pubmed and Cochrane was used to narrow search results.

Table 1. Keywords and Synonyms of The Study Search Strategy

P	I	C	O	S
• Golf • Golfer • Elite Golfer • Professional Golfer • Amateur Golfer • Recreational Golfer	• Biomechanics • Kinetics • Kinematics • Golf Swing • Ball Hitting	• Biomechanics • Kinetics • Kinematics • Golf Swing • Ball Hitting	• Golf Performance • Performance	• Meta Analysis • Systematic Review • Randomized Controlled Trial • Prospective Cohort • Case Control

Source: Author

The search results from each database were then saved in .ris or .bib or .text format. The file was imported into Mendeley desktop, followed by duplication checking. After reducing articles containing duplication, the total number of articles was checked and the articles included in the review were determined. The author selected articles from search results by reading the article titles and abstracts that matched the PICO keywords. Next, the author

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examined the accessibility of articles that matched the PICO keywords and the availability of the full text of the article. The researcher also evaluated its suitability to the PICO criteria and inclusion criteria which included:

1. articles in Indonesian and English language;
2. articles with full-text access;
3. articles published in the last 10 years (2015 – 2024);
4. articles including golf players aged > 18 years, having been playing golf for any length of time, both amateur/ recreational and professional/elite golfers as the population (P);
5. articles discussing various conditions and positions of swing and ball hit when playing golf biomechanically, both kinetically and kinematically, for any duration and observed until the observation period was complete, as the type of intervention (I);
6. comparison (C) : -
7. articles discussing improved golf performance as the outcome using any measurement method, for any duration (O);
8. articles using Systematic Review and Meta-Analysis for RCT, Experimental Study, Randomized Controlled Trial (RCT), Prospective Cohort Study, and Case-Control as the study design.

Articles meeting the inclusion criteria were then subjected to a critical review method based on the study design found using the Critical Appraisal Checklist for an Article on Harm or Causation and the Systematic Review Critical Appraisal Tools Worksheet using FAITH from the University of Oxford which involved 3 steps, including validity assessment, importance assessment, and applicability assessment. The final step was determining the level of evidence by using the Oxford Center for Evidence Based Medicine 2011 Levels of Evidence and determining recommendations using the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE).

RESULTS

Based on the search process carried out using keywords and synonyms on Pubmed, Cochrane, Scopus, and hand searching, 1051 articles were obtained after removing duplicate articles. The articles were screened based on the title and abstract. This process excluded 1036 articles that were irrelevant, not accessible for full-text, not in English/Indonesian language, and did not match the PICO keywords. After the exclusion, 15 articles were read in full and included in the review. The PICO and study characteristics of articles entering the review stage are presented in Table 2.

The search results found 15 articles consisting of 1 systematic review, 5 experimental studies, and 9 prospective cohorts, as well as critical appraisals that were valid, important, and applicable with slight adjustments. Most studies measured X-factor, stretch factor, GFMS, GMS measurements, and swing biomechanics during rotation of the trunk, thorax, spine, and pelvis, including hand grip position and foot pressure when standing, on at least one golf performance such as CHS, BS, and swing sequence, showing a significant relationship. Based on GRADE, the results obtained had a moderate recommendation level. The obtained result was quite confident in the effects and estimates. The actual results were likely to be close to the estimates made in the study but it was still possible that they were substantially different.

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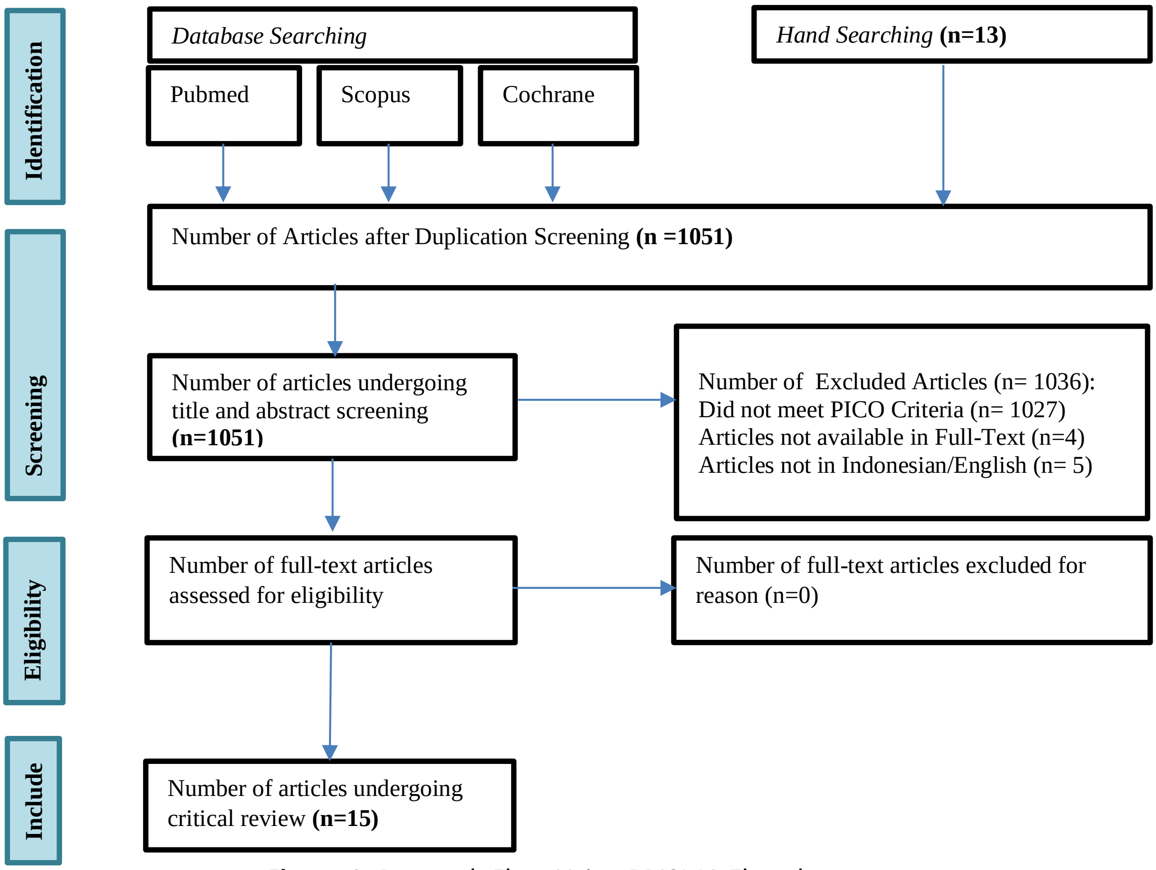

Figure 1. Research Flow Using PRISMA Flowchart
Source: Author

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

Researcher (Year)	Country	N	Design Study	Characteristics of Study (P)	Intervention and Comparator (I, C)	Outcome	Result Finding
Lamb PF and Pataky PC (2018) (Lamb & Pataky, 2018)	Germany	16 male right-handed golfers (age = 28 ± 7.0 years, handicap = 4.1 ± 4.0, range +2.5–10.0)	Experimental Study	1. Samples were selected based on the 4º (±4º) difference in X-factor between “easy” and “hard” swings found by Meister et al. (2011); 2. All golfers were in good health and free of injury; 3. Using 5- and 6-iron.	Pelvis-thorax coupling	Clubhead Speed (CHS) with 3 conditions of effort in hitting and swinging: "minus", "normal", and "plus"	1. Thoracic range of motion and pelvic range of motion showed significant main effects on swing and hitting efforts with the club; 2. No significant differences were found in the X-Factor for either swing or hitting efforts; 3. X-Factor stretch showed a significant difference in golf swing movement and hitting efforts; 4. The continuous relative phase (CRP) results showed evidence of a strain shortening cycle during the downswing and this was more clearly visible at the end of the downswing as swing effort increased; 5. The large inter-individual variability of CRP suggested the need for individual analysis when investigating coordination in the golf swing.
Parker J, Hellstrom J, and Ollson MC (2022) (Parker et al., 2022)	Sweden	20 elite right-handed golfers; 10 females and 10 males, aged 21.6 ± 2.0 years	Prospective Cohort Study	1. Having a maximum handicap of −2.0 registered with the Swedish golf association (average +0.7 ± 1.4 strokes); 2. Playing competitive golf at an international level.	Kinematic differences between female and male elite golfers	CHS and Carry Distance (CD)	1. Strong evidence that the performance driver variables in the form of CHS and CD decreased in female compared to male and 2 kinematic variables; 2. The time to reduce peak arm velocity during the downswing and the peak wrist velocity angle was slower in female; 3. Strong evidence showed that individual swing characteristics among participants was a constant factor as a determinant of CHS, both male and female, but not a determinant of CD; 4. To improve driver performance in high-level golfers, it is necessary to be aware of the variables that determine CHS and CD which are different between male and female. If the aim is

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							to improve CHS, then one must not forget the importance of individual swing characteristics.
Sorbie GG, et al. (2018) (Sorbie et al., 2018)	Scotland	15 right handed male golfers	Experimental Study	1. Height: 186.0+5.3 cm, weight: 80.9+6.9 kg, age: 23.8+2.9 years, handicap according to the English Golf Association: 3.3+1.7. 2. Had no history of persistent lower back pain and/or musculoskeletal disorders; 3. Did not perform conditioning or resistance training 48 hours before the testing session; 4. Participants were required to demonstrate a 'modern' golf swing and not a 'classic swing' as judged by members of the Professional Golfers Association (PGA).	X-Factor, X-Factor stretch before and after golf practice	Long-term golf game performance	1. There was a significant increase in X-Factor (p=0.00, d=0.22) and X-Factor stretch (p=0.02, day=0.25) after exercise; 2. X-Factor increased from 52.82+5.640 to 54.06+5.610 and significant differences were seen in Club Head Velocity (CHV) (p=0.00, d=0.35), Ball Velocity (BV) (p=0.01, d=0.21) and CD (p=0.00, d=0.29) after the training session; 3. Taking several golf shots did not contribute to muscle fatigue in long-term golf game performance; 4. Hitting 100 golf strokes would increase the X-Factor, X-Factor stretch pattern, and performance variables, and could ultimately improve long game performance.
Speariett S and Armstrong R (2019) (Speariett & Armstrong, 2019)	United Kingdom	11 amateur golfers: 5 males and 6 females	Cohort Study, Clinical Measurement ; Correlational Study Design	1. Male: age: 37.2±18.7 years; height: 184.4±9.6cm; body mass: 89.5±13.4kg; handicap: 9±6.6); 2. Female: age: 53.7±15.0 years; height: 166.8± 5.5cm; body mass: 67.9±16.6kg; handicap: 13±6.1); 3. Participants were recruited from English golf clubs; 4. Inclusion criteria: maximum active Congu handicap of 28 for males and 36 for females; weekly golf participation in the 1 year before the study; minimum 5 years of golfing experience and had to be between 18 and 70 years of age;	1. Titleist Performance Institute golf specific functional movement screening (GSFMS) composite consisted of 17 individual tests with a maximum achievable combined score of 36 points (pts). 2. Individual element scores	Golf performance by assessing: 1. Player handicap; 2. CHS; 3. Side accuracy; 4. Ball speed (BS); 5. Peak pelvic rotation speed; 6. Sequence of swing movements (swing sequence); and 7. Common swing mistakes.	1. There was a significant relationship between the GSFMS composite score and handicap (r= -0.779, p=0.005); CHS (r= 0.701, p=0.016); BS (r= 0.674, p=0.023); and peak pelvic rotation speed (r= 0.687, p=0.019); 2. There was a significant relationship between the 90°90° golf position with CHS (r=0.716, p=0.013), S (r=0.777, p=0.005), sitting trunk rotation and peak pelvic rotation speed (r=0.606, p = 0.048), one-leg balance and handicap (r=- 0.722, p=0.012), trunk rotation and handicap (r=-0.637, p=0.039) and peak pelvic rotation velocity (r=0.741, p=0.009); 3. Single leg balance, overhead deep squat, and pelvic tilt were the most difficult GSFMS tests performed by participants;

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				5. Exclusion criteria: experiencing any injury in the previous 6 months that precluded golf participation.			4. The most commonly identified swing errors included loss of posture, slipping, chicken winging, and early hip extension. 5. Golf handicap (r= -0.779, p=0.005) was in the value ranged between 0.60 and 0.80. The lowest handicap of 0 had the highest combined GSFMS score of 29.
Gould ZI, et al. (2021) (Gould et al., 2021)	United Kingdom	62 golfers (40 males, 22 females) with low handicaps from the National Development Pathway	Cohort Study, Clinical Measurement ; Correlational Study Design	1. Age: 15.4 + 2.4, ranged from 11 to 26 years, height 169.8cm, body mass 61.9kg, and handicap 4 (ranged between +4 and 15); 2. Selected on behalf of the national organization as the best player for their age group in the country; 3. Junior and adult golfers; 4. Providing written consent and, for those under 18 years of age, parental consent was also requested.	Golf movement screen (GMS) in the form of 10 movements: trunk inclination, seated hamstring, seated thoracic rotation, rotation over fixed foot, lunge, overhead squat, basic balance, mini squat, diamonds, and side plank. Body segments were scored, 1 for success, 0 for failure, then the total score for each movement was accumulated. The total value of each movement would produce the total GMS value.	1. X-factor; 2. Biomechanical movements of the pelvis, thorax and spine at 3 separate points during the golf swing, top of the backswing and impact during the backswing.	1. All GMS movements were significantly correlated with at least one measure of spinal control at either peak backswing or impact; 2. 4 out of 10 exercises significantly correlated with X-Factor (r = 0.25–0.33; p=0.05): side plank (r=0.33; p = 0.05), trunk inclination (r= 0.30; p = 0.05), squat, and basic balance (r= 0.25; p , 0.05); 3. 4 exercises moderately correlated with spinal rotation at the peak of the backswing (trunk inclination r = 0.36, thoracic rotation r= 0.30; squat r= 0.32; basic balance r= 0.31); 4. Side bend of the spine was significantly correlated with 9 of 10 exercises and total GMS score (r = 0.26–0.53, p =0.05); 5. Pelvic and chest movements at the top of the backswing were minimally correlated with GMS; 6. Pelvic sway at the peak of the backswing was significantly associated with rotation over fixed foot (r = 0.37), diamonds (r = 0.31), side plank (r = 0.27), pelvic lift to the seated hamstring test (r = 0.32), and basic balance (r =0.41); 7. At impact, trunk tilt, chest rotation, and squat had a small to moderate significant relationship with biomechanical movements (p = 0.05);

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							8. Movement competency was closely related to swing mechanics; 9. The strength of the relationship increased to r= 0.49 when plank, trunk inclination, and lunges were combined; 10. Golfers who scored better on the GMS had better spinal control and could create a greater X-factor during the golf swing.
Izumoto Y, et al. (2020) (Izumoto, Kurihara, Sato, et al., 2020)	Japan	17 male collegiate golfers	Quasi-Experimental Design	1. Age characteristics: 20.2 ± 0.8 years; height: 1.71 ± 0.05 m; body mass: 67.9 ± 9.9 kg; 2. Had a minimum of 4 years golf experience; 3. Participated in competitions, with a best score of 65.6 ± 2.0 strokes/lap and an average score of 75.1 ± 2.6 strokes/lap a month before the experiment.	1. Changes in angular momentum during the golf swing (participants were asked to make 5 swings and golf shots) in 15 segments; 2. Total angular momentum in 15 segments about the center of mass of the whole body and segmental contributions from the trunk, arms, legs, and stick.	CHS	1. The angular momentum of the club-body system and the club increased from the top of backswing to impact; 2. Arm angular momentum reached maximum before downward midswing; 3. The body's angular momentum peaked after the downward midswing; 4. Only the maximum angular momentum of the trunk had a significant effect on CHS (R2 = 0.494, p = 0.002); 5. Only for the trunk was it found that CHS was negatively correlated with the relative difference between maximum angular momentum and impact angular moment (r= −0.492, p = 0.045); 6. CHS could be accelerated by increasing the angular momentum of the body-club system without sequential movement from proximal (trunk) to distal (arm) segments; 7. The large angular momentum of the club shaft at the end of the downswing was important in accelerating CHS.
Pataky TC (2015) (Pataky, 2015)	Japan	32 amateur right-handed golfers	Experimental Study	1. Characteristics: age: 45.2 ± 13.1 years; height: 176.2 ± 6.0 cm; mass: 76.4 ± 7.7 kg; handicap index: between 2.7 to 25 (mean: 15.8 ± 6.2);	Foot-loading location was said to underlie load sharing through the distribution of	CHS	1. Significant positive correlation between CHS and PP on the lateral target leg (P<0.05) → indicating not only weight transfer but also the location of weight transfer might be an

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				2. Each participant stood on the synthetic grass at the driving range and took 10 driver shots from the rubber tee by first warming up followed by 10-20 practice swings, then recording 10 consecutive swings; 3. All participants were fitted with the same golf shoe model (Lunarlon Control, Nike Inc., Beaverton, OR, USA) before the experiment.	maximum plantar pressure (PP) within the shoe that occured during the golf swing.		important determinant of CHS in amateur golfers; 2. The average PP distribution was asymmetric with the highest target foot pressures and was positively correlated with CHS at the lateral forefoot, heel, and hallux, and a weak negative correlation at the posterior hindfoot, posterior heel, and medial forefoot and hallux pressures; 3. Different participants produced qualitatively different PP distributions: participants with the highest CHS tended to produce high lateral target foot pressure, and participants with lower CHS tended not to place the same load on the lateral target foot, and also had different PP distributions more variable.
D'Arcy M, et al. (2021) (D'Arcy et al., 2021)	Germany	28 (11 females, 17 males) amateur recreational golfers	Experimental Study in the form of a 5-level "within-subjects"-factor design, with the range of molded GPs increased from +30° (very weak/counter clockwise) to −30° (very strong/clockwise)	1. Characteristics: mean age 47.0 years (SD = 19.7); average golfing experience 22.0 years (SD = 17.6); and handicap between −3 to −36 (M = −15.0, SD = 8.0); The driver CHS varied between 120 km/hour to 120 km/hour. 153 km/h (M = 138.93 km/h, SD = 14.41); 2. Right-handed and had no potential for hand or wrist injuries; 3. Grip position (GP) category used a visual assessment of weak or strong based on the number of knuckles visible on the left GP when viewed from a front perspective: GP was very weak (+30°), (less than one knuckle was visible on the left hand), weak GP (one knuckle visible), moderately weak GP (+15°) (more than one but less than two)	1. The effects of the 5 GPs of weak, neutral, and strong were systematically manipulated. Each GP was done for 9 repetitions; 2. The effect of the GP being rotated clockwise and counterclockwise ; 3. Comparing participants who were manipulated with those who	1. Accuracy and distance related to driving performance: lateral deviation (left and right), absolute accuracy, club face angle, club path angle, face to path angle, launch direction, CHS, and total driving distance; 2. Symmetrical effect on accuracy and distance driving performance.	1. GP significantly influenced 6 dependent variables on accuracy (sideways deviation, left and right), absolute accuracy, club face angle, club path angle, face to path angle, launch direction), and two results on distance (CHS and driving total distance); 2. Overall, optimal performance in accuracy and driving distance was found for neutral and strong GP; 3. Weaker GP showed much more detrimental effects on accuracy and distance; 4. These results demonstrated the effects of asymmetric outcomes from symmetric GP manipulation.

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				neutral (0°) (two knuckles visible), moderately strong GP (−15°) (more than two but less than three knuckles), strong GP (three knuckles), very strong GP (−30°) (more than three knuckles).	performed GP naturally.		
Joyce C (2017) (Joyce, 2017)	Australia	15 right-handed male golfers with low handicaps	Prospective Cohort Study	1. Study characteristics: age = 22.7 ± 4.3 years, golf handicap = 2.5 ± 1.9; 2. Complete the modified Nordic Low Back Pain questionnaire and confirm there had been no back pain in the last 12 months; 3. Not currently in any form of conditioning or resistance training program that could affect flexibility results; 4. All participants used a "modern" golf swing, NOT a "classic" swing as confirmed by two teaching professionals from the Australian Professional Golfers Association independently; 5. During testing, participants wore bicycle shorts, golf gloves, drivers and golf shoes respectively.	1. Axial rotational flexibility of the upper and lower trunk; 2. Flexibility regarding the X-factor and 6 kinematic variables of the golf swing.	1. X-Factor; 2. CHS	1. Pearson correlation showed that trunk extension and lateral bending were moderately related to the x factor, but not to axial rotational flexibility; 2. Trunk extension flexibility showed a negative correlation with lower trunk axial rotation at the top of backswing ($r = -0.519$); 3. Bending flexibility of the trunk to the left lateral direction showed a positive correlation with the axial rotation of the trunk at the top of backswing ($r = 0.650$) and the maximum axial rotation of trunk ($r = 0.644$); 4. Bending flexibility of trunk to the right lateral direction showed a negative correlation with maximum axial rotation of trunk ($r = -0.583$); 5. 3 axial rotational flexibility variables, and 6 golf swing kinematic variables were associated with faster CHS; 6. 9 of the 12 x-factor variables related to golf swing flexibility and kinematics were significantly ($P < 0.05$) related to CHS. 4 of the 9 selected variables with the strongest association ($\beta > .20$) were maximum lower trunk axial rotation ($\beta = -.52$, $t(15) = 26.23$, $P < .01$), lower trunk axial rotation at the top of the backswing ($\beta = .34$, $t(15) = 11.87$, $P < .01$), trunk axial rotation at the top of backswing ($\beta = .28$, $t(15) = 88.65$, $P < .01$) and lower left trunk

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							axial rotation flexibility (β =.23, t(15) = 65.64, P < .01); 7. From the 4 variables selected, maximum axial rotation of the lower stem was the only variable that was negatively related to faster CHS. The other 2 flexibility variables were right axial rotational flexibility of trunk (β =.07, t (15) = 3.83, P < .05) and left axial rotational flexibility of the trunk (β = –.10, t(15) = 35, 80, P < 0.01), which was negatively associated with faster CHS; 8. Skilled golfers who experienced increased axial rotational flexibility did not necessarily exploit it to increase the x-factor, and these results supported the importance of flexibility and multisegment interactions for improving golf performance in skilled golfers.
Choi A, et al. (2016) (Choi et al., 2016)	Korean	21 right-handed male professional golfers	Prospective Cohort Study	1. Characteristics: age: 31 ± 6 years, Height: 177.5 ± 8.7 cm, weight: 79.2 ± 10.0 kg, and handicap score below 0; 2. No history of musculoskeletal disorders; 3. Golfers who experienced pain in joints or related muscles were excluded from the trial.	Inter-joint coordination between the rotational movements of each hip and trunk used a relatively continuous phase	Swing performance represented by CHS measurements	1. More typical inter-joint coordination was shown in the hips/front trunk compared to the hips/back trunk; 2. 3 characteristics of hip/front trunk coordination had a significant relationship with CHS at impact (r < –0.5); 3. The increasing difference in rotation between the lead hip and trunk throughout the downswing phase and the faster rotation of the lead hip compared to the trunk at the beginning of the downswing played an important role in increasing CHS.
Joyce C, et al. (2016) (Joyce et al., 2016)	Australia	35 high-level amateur golfers	Prospective Cohort Study	1. Characteristics: age = 23.8 ± 2.1 years, registered golf handicap = 5 ± 1.9; 2. Each participant was given a modified Nordic Low Back Pain questionnaire and confirmed the	1. Variables related to crunch factors (lateral bending of the trunk and axial rotation speed of the	1. Swing (CHS) 2. Launch (launch angle)	1. There was a positive relationship between the upper and lower trunk and axial rotation speed (r (35) = 0.47, P < 0.01); 2. Cross correlation analysis showed that there was a strong coupling relationship for the

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

Researcher (Year)	Country	N	Design Study	Characteristics of Study (P)	Intervention and Comparator (I, C)	Outcome	Result Finding
				absence of back pain in the last 12 months; 3. Using a "modern" swing NOT a "classic" swing as confirmed through qualitative video analysis of each participant swing by 2 professional teachers from the Australian Professional Golfers Association; 4. Using the same famous brand of golf balls; 5. Participants wore their own bicycle shorts, golf gloves, driver and golf shoes.	trunk) in the upper and lower trunk; 2. Variables related to the crunch factor.		crunch factor ($R2 = 0.98$) between the upper and lower trunk; 3. Faster CHS and lower golf ball launch angles were associated with reduced lateral bending in the lower trunk.
Kim TG and So WY (2017) (Kim & So, 2017)	Korean	25 healthy male golfers (15 professionals (PRO) and 10 amateurs (AMA))	Prospective Cohort Study	Had no musculoskeletal injury or history of surgery.	1. Differences in isokinetic strength of knee flexors and extensors of professional and amateur golfers; 2. Comparison of the kinematic movement of the knee joint during the downswing in professional and amateur golfers using a driver and 5 iron clubs.	1. Development of efficient physical exercise; 2. Improved golf performance.	1. PRO golfers had a narrower minimum angle between the thigh and lower leg at the trail knee than the AMA golfer; 2. Regardless of the type of club used, the angular velocity of the lead knee was faster during the downswing with a 5-iron club in AMA golfers compared to PRO golfers; 3. PRO and AMA golfers had a wider minimum angle between the thigh and lower leg, smaller total range of motion, and slower trail knee angular velocity when swinging the 5-iron than when swinging the driver.
Dale RB and Brumitt J (2016) (Dale & Brumitt, 2016)	United States of America	13 golfers	Prospective Cohort Study	1. Characteristics: age = 38.8 ± 4.2 years, height = 1.8 ± 0.1 m, weight = 83.6 ± 3.0 kg, and had experience of 16.0 ± 1.4 years with a level of skill 7.1 ± 0.8 strokes	Comparison of kinetic, kinematic, and performance variables associated with the	X-Factor kinematic data and spinal kinetics; Performance related: Club Head	1. Significant decrease for X-Factor ($p < 0.05$) between full swing and short swing; 2. Shortened swing improved spinal compression force from 7.6 ± 1.4 to 7.0 ± 1.7 N (normalized by body weight, $p = 0.01$) and significantly

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Researcher (Year)	Country	N	Design Study	Characteristics of Study (P)	Intervention and Comparator (I, C)	Outcome	Result Finding
				according to the United States Golf Association (USGA) handicap; 2. Had no history of any injury or surgery in the past year; 3. Had to have played golf for at least 3 years with a USGA handicap of 10 or less; 4. Each golfer had to swing as usual, but with reduced body rotation during the backswing, and practice several swings to achieve an acceptable backswing angle; 5. Participants performed a total of 20 swings divided into 4 sets of 5 swings, alternating between short swings and full swings with each set of 5 swings, and a total of 10 swings for each type of swing; 6. Participants used their own 7-iron club for all swings to ensure consistency.	full and short modern backswing in a group of modern swing (one-plane) skilled golfers.	Velocity (CHV), shot distance, and accuracy (distance from the target line).	reduced CHV ($p < 0.05$) of ~2 m/s with a concomitant reduction in shot distance of ~10 m ($p < 0.05$).
Khuyagbaatar B, et al. (2019) (Khuyagbaatar et al., 2019)	Korean	10 right-handed male golfers with low handicaps	Prospective Cohort Study	1. Characteristics: age= 23.2+1.6 years; Height = 175.7+3.8 cm; weight, 74.4+10.4 kg; handicap, 2.6+1.3; 2. Each participant performed warm-up, stretching and golf swing exercises using their own golf shoes and driver for 10 minutes; 3. Participants then performed one stroke with their driver.	Identified the major joints, including the upper and lower trunk	Golf performance: X-Factor and pelvic motion	1. Based on regression analysis: right knee adduction, right shoulder external rotation, and left elbow extension on the ball leading to the top of the backswing; left knee adduction, as well as right lower trunk bending with left rotation at the top of the backswing until the end of follow-up were predictor variables for the X-Factor; 2. For hip movement, a greater number of joint angles was associated with a backward tilt of the pelvis during the backswing and a movement of the pelvis toward the target with rotation to the right during the downswing/followthrough.

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

Researcher (Year)	Country	N	Design Study	Characteristics of Study (P)	Intervention and Comparator (I, C)	Outcome	Result Finding
Merry C, et al. (2022) (Merry et al., 2022)	United Kingdom	25 articles (from an initial total of 897 articles) were selected for review	Systematic Review and Meta-Analysis	1. Electronic databases: PubMed, SPORT discus, Scopus, Science Direct and Google Scholar with the keywords “biomechanics” AND “golf putting”; 2. Published between 2010 and 2020; 3. Inclusion criteria: (1) contained a kinematic approach to golf putting which included accuracy and precision; (2) skill level from beginner to professional (including all handicaps), age, and non-injured population; (3) only articles in English; 4. Average skills: Professional ≤ 0, Elite = 1–6, High = 6–10, Amateur = 10–20, Beginner ≥ 20; 5. The type of intervention was classic, and all results were assessed based on the level of experience and age.	1. Golf kinematics assessment; 2. Differences between elite and amateur golfers.	1. Improved golf putting accuracy and precision; 2. Club head speed and putter face angle (°) at impact	1. A kinematic assessment approach starting from the putter face angle (°) at impact, putter path, vertical point, and backswing could help improve golf putting accuracy and precision thereby increasing putt success and reducing the overall score; 2. Elite golfers had a slightly slower speed, but more controlled stroke angle, more accurate and more precise direction and angle of the putter face at impact, thereby increasing their accuracy in completing more successful putts. Despite this, there was no significant difference between the club head speed of elite and amateur golfers; 3. Both professional and elite players had a neutral slope angle, but professional golfers were more experienced in putting technique; 4. Elite golfers appeared to be the most efficient in putting, while amateur golfers showed lower efficiency. Amateur golfers had a low vertical point, smaller rise angle, and increased shaft angle – which would increase backspin, limiting ball throwing efficiency.

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DISCUSSION

A golfer performance can be influenced by various factors, one of which is biomechanical condition. Based on the results of the evidence-based case review in this study, the emergence of the modern swing with X-factor, X-factor stretch, and crunch factor could improve performance (Cole & Grimshaw, 2015). This may be the reason why the modern swing is one of the inclusion criteria requirements for several studies screened in this review. Another study that examined the X-factor and X-factor stretch found that the range of motion of the thorax and pelvis was related to swing and ball hit efforts (Lamb & Pataky, 2018).

There are several factors that are believed to influence the X-factor, one of which is the ability to extend and bend lateral to the trunk which is closely related to the golfer flexibility (Joyce, 2017). Left lateral bending flexibility of the trunk had shown a positive correlation with trunk axial rotation at the peak of the backswing and maximum trunk axial rotation. Furthermore, according to a study conducted by Joyce (2017), the axial rotation of the trunk at the top of the backswing would be positively correlated to CHS, conversely, the maximum axial rotation of the trunk would be negatively correlated. Reducing the lateral bending of the lower trunk was said to accelerate CHS (Joyce et al., 2016).

Some other predictors for the X-factors are right and left knee adduction, right shoulder external rotation, left elbow extension at the peak of the backswing, right lower trunk bending with left axial rotation at the peak of the backswing until the end of the followthrough (Khuyagbaatar et al., 2019). Apart from that, other research also explained that the type of swing, full or shortened, could also influence the X-factor. A shortened swing would reduce the X-factor and CHV (Dale & Brumitt, 2016). On the other hand, shortening the swing, especially during the backswing, would reduce compression forces and spinal loads, thereby protecting golfers from low back pain (LBP) (N. Edwards et al., 2020; N. A. Edwards et al., 2023).

Providing functional golf movements, such as side plank, trunk inclination, squats, lunges, and basic balance could produce greater X-factor scores (Gould et al., 2021). The combined score also showed significant results on CHS, BS, speed pelvic peak rotation, and handicap (Speariett & Armstrong, 2019). The amount of practice could also influence the X-factor and X-factor stretch, where practicing 100 golf strokes would allow an increase in the X-factor, X-factor stretch, CHV, BV, and CD, influencing long-term golf performance (Sorbie et al., 2018).

When compared with the X-factor, the X-factor stretch itself showed a more significant increase in enlarging a golfer ability to swing and hit, especially at the end of the downswing. Thus, the X-factor stretch seemed to be more important than X-factor for the golf performance, in this case CHS (Choi et al., 2016). However, with large variability between individuals, further study is still needed regarding the relationship between X-factor and X-factor stretch on performance (Lamb & Pataky, 2018).

Other factors that might affect performance included the club large angular momentum at the start of downswing (Izumoto, Kurihara, Sato, et al., 2020). Female gender had lower CHS and CD values, where CHS itself was also related to individual swing characteristics, both female and male (Parker et al., 2022). Weight transfer and weight transfer location in the plantar pressure distribution within the shoe were also correlated with CHS (Pataky, 2015). Likewise, a neutral and strong GP would help achieve optimal performance (D'Arcy et al., 2021). Lastly, skill differences between amateur and professional golfers could also affect performance. Golf professionals were said to have a narrower minimum angle between the thigh and lower leg at the trail knee (Kim & So, 2017), with lower speed, a slower putter face

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angle (°), and more controlled swing angle so that the shot was more accurate, precise, and efficient (Merry et al., 2022).

Returned to the case scenario, it was quite difficult to find articles that truly matched the patient characteristics in the scenario, especially in terms of handicap level. Only 3 articles from Speariett S and Armstrong R (2019), Pataky TC (2015), and Merry C, et al. (2022) were close to the patient characteristics. However, in general, most of the findings from the fifteen selected articles seemed to strengthen each other so that they could still be considered for benchmarking with modifications and adjustments.

The flexibility of patient in the case scenario, especially his left trunk lateral flexion, tended to be limited. In fact, flexibility is one of the components that can affect the X-factor and subsequently affect golf performance. Upper trunk rotation, especially in the thoracic segment, was also more limited so it was estimated that this would reduce the patient X-factor, X-factor stretch, and crunch factor values which would again affect their performance. In this case, patients might be advised to increase his flexibility and also do some functional golf movements as muscle strength training to improve performance. Furthermore, not only for patients, providing exercises that can increase flexibility and functional golf movement capabilities by paying attention to the X-factor, X-factor stretch, and crunch factor can also be implemented in the training program for golf athletes or recreational golfers who have almost similar biomechanical conditions.

The results of this evidence-based case review found that 5 of 15 articles were found in Asia, including Korea and Japan, so that participant characteristics more closely resembled conditions in Indonesia. Apart from that, the assessment of movement and golf performance was carried out using tools so that it was more objective. The existing research results also mostly appeared to strengthen/confirm each other.

On the other hand, some studies asked participants to use their own clubs, while other studies equated types of clubs and even balls. Each had its own advantages and disadvantages. Using the owned club would ensure that golfers could swing more naturally and did not need to adapt, but this might be a bias factor because it could affect the results of their performance. While using the same stick could further minimize this bias factor, participants needed more time to adapt to the new stick. Another weakness of this study is the use of 3 databases accompanied by hand searching, which still allows suitable articles from other databases to not be recalled. In addition, the decision to take articles up to the review stage was made based on the author agreement. Even though there was PICO criteria, the element of subjectivity in elections could not be eliminated.

In the development of further research, it is expected that there will be more research using RCTs or cohort studies on golf performance involving Indonesian golfers, both recreational and professional golfers. In addition, the study is also expected to cover broader subject criteria from various handicap levels and can shift from the laboratory to more natural settings, such as in the field when the player is in actual competition or training activities.

CONCLUSION

X-factor, X-factor stretch, crunch factor, including grip position, and stance are the aspects that can differentiate performance of golfers. Understanding the biomechanics of the golf swing, especially in an individually-tailored program can help optimize a golfer performance. Apart from that, differences in gender and the characteristics of individual swing skills, especially between professional and amateur, also need to be taken into consideration when providing golf training and arranging the performance targets to achieve. Further research is

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expected to include Indonesian golfers, with various handicap levels for the subject criteria, in various research designs, such as RCTs and cohort studies.

AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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