KINEMATIC DETERMINANTS OF THE INSTEP SOCCER KICK IN ELITE ADULT SOCCER PLAYERS: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Kicking is considered the defining action of the sport of soccer, with the instep kick being the most widely used variant. Until now, there have been no previous systematic reviews exploring the kinematic characteristics of elite soccer players over the age of 18. Previous investigations have either used narrative review study designs or had not isolated the adult elite level population.

Objective: The objective of this systematic review is to describe the kinematics associated with the instep soccer kick in elite adult soccer players over the age of 18.

Methods: PRISMA guidelines were utilized. Articles were retrieved from searches across three online databases (MEDLINE, CINAHL, and SPORTDiscus). Studies investigating instep kicking kinematics in elite level soccer athletes over the age of 18 were eligible for inclusion. The methodological quality of the included studies was assessed using a modified quality assessment tool for kinematic studies developed around the major research aim of this review.

Results: Of 1836 papers identified initially, 12 papers were deemed directly relevant following screening. Data was presented sequentially according to the five distinct kinematic phases: preparation, backswing, limb cocking, acceleration, and follow-through. Coordinated proximal to distal sequencing of the kick leg during the downswing was observed in all elite athletes, along with eccentric formation and concentric release of a 'tension arc' between the torso, pelvis and kicking hip.

Conclusions: The results of this review descriptively demonstrate important kinematic characteristics related to timing, body positioning/coordination, and anatomical angular/linear velocities in elite adult soccer player instep kicking. However, according to quality assessment of the included studies, improved scientific and kinematic data collection methods are necessary in the future – specifically in achieving better reporting on segment coordinate systems, model properties and degrees of freedom, axes and order of rotations, and appropriate variability/reliability/repeatability procedures.

Keywords: soccer, kinematics, elite athletes, instep kick, adults

INTRODUCTION

Soccer (also known as Association Football or simply football in many countries) is reputedly the most popular sport in the world, with the 2018 FIFA World Cup™ having captured an estimated 3.572 billion viewers[1]. Kicking is considered the defining action of the sport, so it is relevant and appropriate to examine and review the published literature to understand this essential skill. A variety of kicking techniques can be used in offensive and defensive scenarios for the purposes of passing, possession, and scoring[2]. More specifically, the "instep kick" is known to be the most widely used variant of kicking in soccer, performed by contacting the ball with the dorsum of the foot while plantarflexed[3]. This kicking technique generates a high ball velocity and is primarily used during game scenarios requiring the ball to travel as quickly as possible, such as shooting on goal, defensive clearances, and long passes[4].

The field of "kinematics" is a subfield of physics and biomechanics, which examines the motion of points, bodies, and systems of bodies without considering the forces that cause them to move[5,6]. Alternatively, "kinetics" takes into consideration the forces and torques used to

generate motion[7]. For the purposes of this review, kinetic evaluation will not be included, as the focus of this paper is centred specifically around instep kick kinematics. Kinematic analysis includes the evaluation of segmental and intersegmental kinematics, their derivatives, and coordination.

The kinematic sequencing of the instep kick includes five distinct phases: preparation, backswing, limb cocking, acceleration, and follow-through[8]. Furthermore, these phases are differentiated by six distinguishing events: kicking leg heel strike, toe-off, peak hip extension, peak knee flexion, ball strike, and toe velocity inflection[8]. Kicking success is dictated by the speed and accuracy of performance[9,10]. Efficient coordination, timing, and execution of these events contribute to the quality and outcome of kicks[11]. In soccer, kicking with high ball velocity can increase scoring opportunities and reduce the likelihood of interception[2]. By kicking with a higher ball velocity, a player can increase the distance from goal in which they can attempt to score, thus increasing the number of scoring opportunities, as well as reducing the likelihood of interception from the opposition by decreasing flight time[2]. Therefore, technical strategies that enhance efficient intersegmental kinematic energy transfers, coordination, and sequencing is important to attain a high ball velocity, which may effectively impact performance[2].

Until now, there have been no known published systematic reviews conducted on the topic of whole-body kinematic description of the instep kicking technique in elite adult soccer players, however, there have been previous narrative reviews published on general populations of soccer players[3,12,13], as well as one systematic review comparing the biomechanical differences between the sexes of all playing levels[14]. The focus of this review is kinematic in nature, as the advances in kinematic data collection methods in the last decades have made a positive impact on our

understanding of the kicking skill. Through analysis of the body of evidence, we aim not only to gain a better understanding of the mechanical effectiveness of the execution of the instep kick, but also to perhaps identify the kinematic factors underlying the successful performance of this complex motor skill, identifying decisive aspects that may be crucial for instep kick performance. The gained knowledge and understanding of this particular technique may also help to enhance the associated learning, coaching, and performance of this skill in footballers of all ages and levels, as well as provide direction for future research. This review considers the instep soccer kick in its kinematic entirety, beginning from the way a player approaches the ball to the end of follow-through. Understanding the mechanism by which athletes produce optimal kicks, as well as the factors that influence performance, are of interest to players and coaches alike. The objective of this systematic review is to describe the kinematics associated with the instep soccer kick in elite adult soccer players over the age of 18.

METHODS

Registration and reporting

This review was registered with the Open Science Framework (OSF) registry on October 27, 2022 (https://doi.org/10.17605/OSF.IO/Q2UBJ). The methods adopted for this review are compliant with the recommended Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) checklist guidelines for systematic reviews[18].

Eligibility criteria

Population: Our systematic review targeted studies involving asymptomatic elite soccer players. An elite soccer player is defined as an athlete that participates either: 1) the highest level of competition (ie: FIFA World Cup); 2) in FIFA accredited & associated federations; or 3) in Non-FIFA accredited National performance in a large sporting nation (ie: Belgium)[15]. Studies using collegiate/intercollegiate athletes and amateur athletes were excluded. Asymptomatic subjects are considered as players without known bodily pains, injuries, or dysfunctions. Players are considered adult if they are of 18 years of age or older.

Outcomes: "Kinematics" is defined as the motion of points, bodies, and systems of bodies without considering the forces that cause them to move[16,17]. The extent of influence can be small and detected only when using specific measurement and research techniques[17]. The outcomes include segmental and intersegmental kinematics, their derivatives, and coordination. The "instep soccer kick" is currently defined to be the most widely used variant of kicking in soccer, made by contacting the ball with the dorsum of the foot[3]. Kinematics are best assessed through motion analysis systems. Although kinetic data (forces enacted that cause movement) may sometimes be reported with kinematic data, kinetic data were omitted as this systematic review is solely focused on the kinematic evaluation of an instep kick. Other biomechanical measures such as EMG data, force plate data, and other data related to force production were also omitted.

***Study designs/characteristics*:** To be eligible, studies targeting the population and outcomes listed above met all of the following criteria: 1) published in a peer-reviewed journal; 2) study designs including: observational studies, cross-sectional, case control studies, cohort studies, and randomized control trials (RCT) where baseline data can be extracted; 3) study population including asymptomatic elite soccer players[15]; 4) outcome measures must assess at least one

kinematic parameter; 5) studies in which the instep soccer kick was assessed using a motion analysis system (electromagnetic or marker-based or inertial sensors) with no restrictions on methodology procedures; 6) athletes that are of 18 years or older; and 7) studies published in the English language. Studies that stratified for those 18 years and older were included. Studies fulfilling any one of the following criteria were excluded: 1) publication types including: guidelines, letters, editorials, commentaries, unpublished manuscripts, dissertations, government reports, books and book chapters, conference proceedings, meeting abstracts, lectures and addresses, consensus development statements, guideline statements; 2) study designs including: case reports, case series, qualitative studies, non-systematic and systematic reviews, clinical practice guidelines, studies not reporting on methodology; and 3) cadaveric or animal studies 4) studies involving symptomatic subjects (ie: pain, injury, or dysfunction); 5) athletes that are non-elite (ie: recreational, amateur or collegiate level); 6) studies observing soccer kicks other than the instep kick (ie: curve kick, chip kick); 7) studies that assess the measurement capabilities/properties of kinematic data collection tools and technology; and 8) athletes that are younger than 18 years of age.

Information sources and search strategy

The search strategy was developed in consultation with an experienced health sciences librarian (see appendix) and was reviewed by a second librarian using the Peer Review of Electronic Search Strategies Checklist[19,20]. MEDLINE, CINAHL, and SPORTDiscus were queried from database inception to April 2022. The search strategy was developed in MEDLINE and adapted to the other bibliographic databases. Search terms included subject headings (e.g., MeSH in MEDLINE) for each database and free text words relevant to our PECO components, which encompass kinematics, soccer, and kicking. A bibliographic citation management

software was used to de-duplicate references electronically across databases and record the number of duplicates identified (EndNote 21, Clarivate, Philadelphia, PA, USA).

Study selection, Pilot Testing of Screening, and Data Extraction

All citations identified by the search strategy were exported into EndNote for reference management and tracking of the screening process. A two-phase (titles and abstracts; full-text articles) screening process was used to select eligible studies. In phase I screening, pairs of independent reviewers screened citation titles and abstracts to determine the eligibility of studies (categorizing studies as possibly relevant or irrelevant). A training exercise was conducted before starting screening to ensure reliability. Team members screened a random sample of 30 records from the literature search based on titles and abstracts using the predefined inclusion and exclusion criteria. Team members conducted a similar training exercise for screening potentially relevant full-text articles using a random sample of 15 full-text articles. Agreement of at least 80% for phase I (i.e., classifying articles as possibly relevant versus irrelevant) and phase II (i.e., relevant versus irrelevant) screening during the training exercise was assessed. If agreement was below these thresholds, all team members would discuss to resolve disagreements and establish clarifications to the eligibility criteria if needed before starting screening

Pairs of independent reviewers screened possibly relevant studies in full text during phase II screening to determine eligibility and document reasons for exclusion. Reviewers met to discuss disagreements and reach consensus on the eligibility of studies. An additional reviewer was involved if consensus could not be reached. Study authors were contacted for supplementary information as needed when screening, assessing risk of bias, and conducting data extraction of studies.

Data items and data collection process

A random sample five articles were piloted for data extraction using three independent reviewers. All three independent reviewers discussed disagreements to form consensus. For all data extraction items of the remaining studies, one reviewer independently extracted the data and a second reviewer verified the extracted data to minimize error. The extracted data included the description of study characteristics (author(s) name, year of publication, setting, and size of the sample); the description of study participants (number, gender, mean age, and level of competition); kinematic outcome measures; and key findings[21]. A qualitative best-evidence synthesis was conducted due to the heterogeneity of the kinematic data reported.

Methodological quality and risk of bias appraisal

The methodological quality of the included studies was assessed using an already existing quality assessment tool used in a previous kinematic study that was further modified to reflect important kinematic methods[22,23,24]. The quality assessment criteria includes 16 questions and were specifically designed for assessing methodological procedures related to kinematic modeling and the reproducibility of a marker set configuration[22,23,24]. It is also used to evaluate the validity of the kinematic data and its respective measurements (Table 1)[24]. Item 5 was modified to "Are the anatomical segments being measured clearly stated?". Item 16 was added to include the evaluator's appraisal on whether or not a fatal methodological flaw was recognized in the study. Item 16 has the ability to exclude/include given articles from synthesis on the basis of whether or not a major methodological flaw is identified. If a major methodological flaw was identified, the respective study would be omitted from inclusion. A scoring system was used to evaluate the quality of each study. Each item was scored as follows: 2 = yes, 1 = limited detail, and 0 = no. An article was deemed high quality if the total score was ≥24/30 (80%)[22,23]. Scores

below 24/30 (80%) were deemed as not high quality. The two reviewers independently assessed the quality of all included studies. As a training exercise to ensure reliability, two reviewers independently appraised a random subset of five included studies using all risk of bias appraisal components of the modified quality assessment tool found in Table 1. Inter-rater reliability between the two reviewers were calculated using Cohen's coefficient kappa (kappa: 0–.29 = week agreement, .30–.59 = moderate agreement, .60–.89 = good agreement, and .90–1 = optimal agreement)[25].

Table 1 Assessment of Research Quality[a]

1.	Are the research objectives or aims clearly stated?
2.	Is the study clearly described?
3.	Are appropriate subject information and anthropometric details provided?
4.	Are the marker/sensors location accurately described?
5.	Is the anatomical segment being measured clearly stated?
6.	Is the reference position used to define anatomical frames reported?
7.	Is the motion analysis equipment and set-up clearly described?
8.	Are the segment coordinate systems clearly defined?
9.	Are the model properties clearly defined for all joints (e.g. degrees of freedom?
10.	Were movement tasks clearly defined?
11.	Are the methods used to describe the axes and order of rotations clearly described or referenced appropriately?
12.	Are appropriate variability/reliability/repeatability procedures documented and reported?
13.	Are the main outcomes of the study stated?
14.	Are the limitations of the study clearly described?
15.	Were conclusions drawn from the study clearly stated?
16.	Is there a fatal methodological flaw identified in the study?

Note: Adapted from Bishop et al.[22]

[a] Items were scored as follows: 2 = yes; 1 = limited detail; 0 = no.

Data Synthesis

We conducted a qualitative best-evidence synthesis due to the heterogeneity of kinematic data reported in the synthesized studies[26]. The data reported in the "Results" section is categorized respectively into 5 distinct phases according to key kinematic sequencing events of the maximal instep kick: preparation, backswing, limb cocking, acceleration, and follow-through[8]. The data presented in each key phase was stratified into 3 subcategories: sequential timing of events, anatomical positioning and ranges of motion, and anatomical angular and linear velocities/accelerations. Each subcategory is further stratified to report data in relation to elite male and elite female players.

Due to the heterogeneity of kinematic data reported, the reviewers determined that a meta-analysis was not appropriate. The evidence synthesis in this review was reported narratively.

RESULTS

Article Selection

Our search retrieved 1836 articles, removed 19 duplicates, and screened 1817 papers for eligibility. The PRISMA flow diagram is used to describe the number of primary studies that were included and excluded in each stage of the selection process (Figure 1). A list of excluded studies at full-text article screening is included in Appendix 2. Twelve articles were eligible for critical appraisal. Of those, all 12 articles were deemed relevant, according to our screening methods, and were included in our synthesis. The inter-rater agreement for phase one screening of articles was $k = 0.62$ (95% CI = 0.56-0.68). The inter-rater agreement for phase two screening of articles was $k = 0.79$ (95% CI = 0.68-0.90).

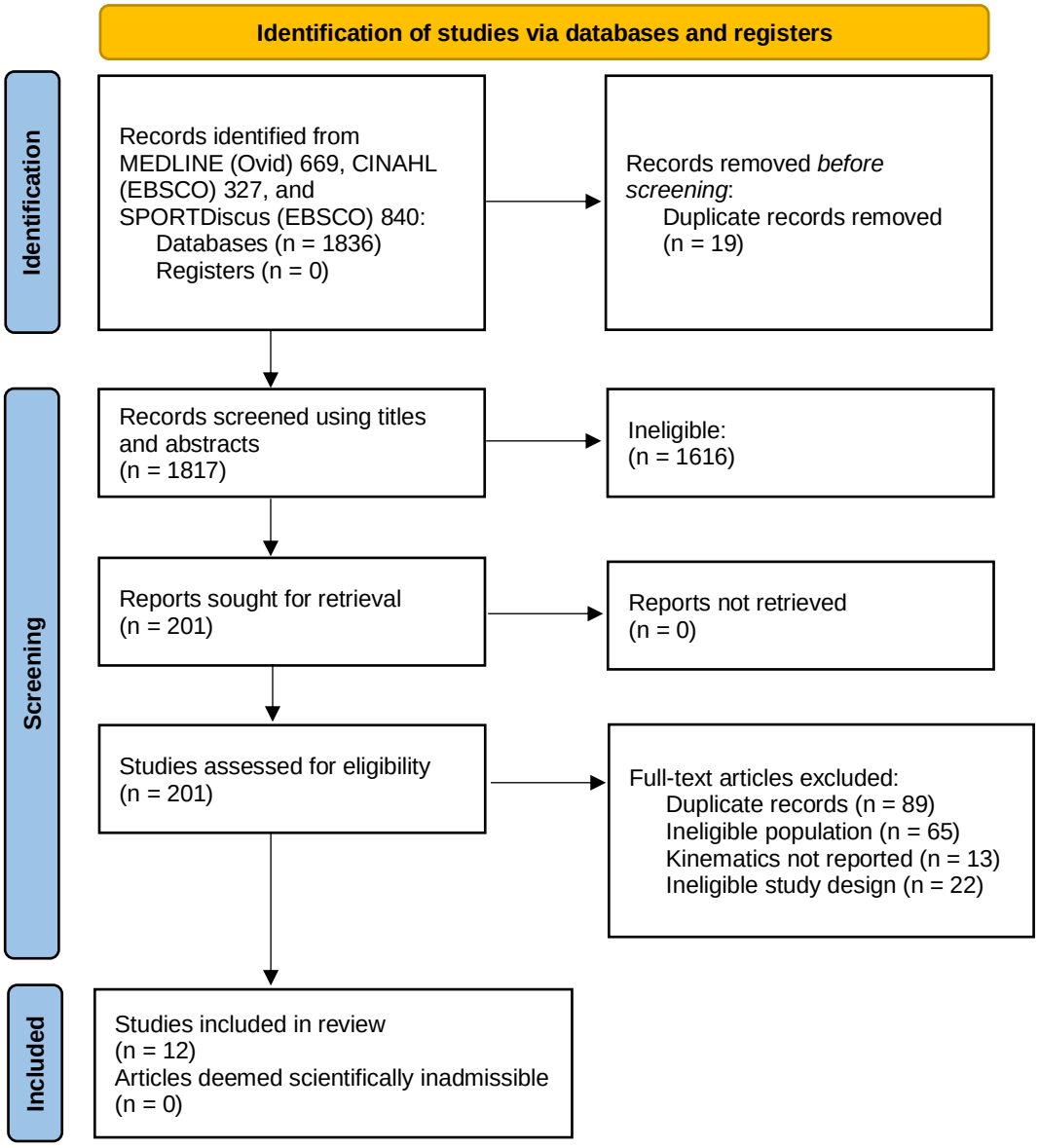


Figure 1 — Preferred Reporting Items for Systematic Review and Meta-Analysis flowchart of the study.

Study Characteristics

Of the 12 articles synthesized, 11 were cross-sectional observational studies[11, 27-36] and 1 was a within-subjects experimental design[37]. Seven studies reported on anatomical positioning and ranges of motion during the kick[28-34]. Seven studies reported on anatomical angular and linear velocities[30-33, 35-36, 38]. One study reported on sequential timing of events during the kick[11]. Four articles reported on the kinematic characteristics of elite females[30, 32-33, 36], while 11 articles reported on the elite male population[11, 28-31, 33-38]. The range of the male mean ages were from 18.8 to 25.6 years of age[11, 28-31, 33-38], while female mean ages ranged between 19 to 22.15 years of age[30, 32-33, 36]. Male mean masses ranged between 70.5 and 87.32 kg[11, 28-31, 33-38], while mean female masses ranged between 58.2 and 61.6 kg[30, 32-33, 36]. Male mean heights ranged from 1.76 to 1.846 m[11,28, 31, 33-38], while female mean heights ranged from 1.64 to 1.69 m[32-33, 36]. The articles synthesized in this systematic review originated from the Netherlands, England, Spain, Portugal, Australia, Brazil, USA, Malaysia, and Italy[11, 28-38]. Eight studies reported conducting the kicking trials on flat ground[11, 28-29, 31, 34, 36-38], 3 studies were conducted on artificial turf[30, 32-33], and 1 study conducted on natural grass[35]. All 12 studies reported on dominant kicking leg kinematics[11, 28-38], while 1 study reported on non-dominant kicking leg kinematics[30]. All 12 articles spoke about the sequencing of events and reported on dominant kicking leg kinematics[11, 28-38].

Table 2 Evidence Table for Data Extraction

Author(s), Year, Study Design	Setting and Subject Characteristics, Number (n) Enrolled	Kinematic Outcomes Measured	Key Findings
Langhout et al., 2016, cross-sectional[28]	Maastricht, The Netherlands, Asymptomatic adult males soccer players from professional Dutch club, n=15 **Mean and Standard Deviation** Age: 22.1 ± 5.0 years Height: 1.81 ± 0.09 m Weight: 80.8 ± 8.42 kg Right footed = 13 Left footed = 2 Setting - Clinical movement lab Maximal effort kicking was compared with submaximal effort kicking (only data from the maximal effort kicking were extracted).	Range of motion (in degrees) of hip flexion, spine flexion, spine rotation, pelvis posterior tilt, and knee flexion at 4 keypoints during the kick (MHE, MKF, KF90, BI) Positive values indicate hip-, spine- and knee flexion, pelvis posterior tilt and spine rotation to the kick side. Negative values indicate hip-, spine- and knee extension, pelvis anterior tilt and spine rotation to the non-kick side Tension arc includes all values at MHE and MKF value of KF. Movement trajectories include the above mentioned max values subtracted by the values at BI.	Mean ROM (degrees) ± SD at: MHE: HF: -31.8 ± 6.0 SF: -3.8 ± 7.2 SR: -21.4 ± 6.6 PPT: -19.5 ± 6.8 KF: 63.8 ± 11.5 MKF: HF: -7.1 ± 8.8 SF: 2.1 ± 8.9 SR: -14.1 ± 23.9 PPT: -4.7 ± 5.2 KF: 111.8 ± 7.1 KF90: HF: 6.7 ± 9.8 SF: 24.2 ± 10.9 SR: 4.3 ± 7.1 PPT: 9.0 ± 7.3 KF: 90.3 ± 1.4 BI:

			HF: 6.4 ± 11.1 SF: 41.4 ± 8.8 SR: 12.4 ± 6.3 PPT: 29.5 ± 5.1 KF: 35.3 ± 10.0 Ball Speed: 98.8 ± 9.0 km/h
Greig et al. 2018, cross-sectional[29]	England, Asymptomatic adult male soccer players from professional English club (Championship Division), n=10 **Mean and Standard Deviation** Age: 20.8 ± 1.7 years Body mass: 72.7 ± 4.7 kg Setting – Lab 8 kicks taken each with 15 min fatigue protocol intervals in between (data extracted only from first kick as no fatigue protocol had occurred yet here).	Thigh and shank ROM, as well as pelvis orientation at Stage 1, 2, and 3 of kicking motion Stage 1 - withdrawal of the thigh and shank during the backswing (time between maximum knee flexion and the initiation of forward rotation of the thigh Stage 2 - up to the instant when the thigh angular velocity is reduced and the shank angular velocity increases Stage 3 – up to the instant of ball contact	**Mean and Standard Deviation Reported** **Stage 2 thigh ROM displacement**: 32 ± 10 degrees **Stage 3 shank ROM displacement**: 64 ± 11 degrees **Touchdown pelvis orientation**: 21.5 ± 8 degrees **Stage 2 pelvis orientation**: 19 ± 7 degrees **Stage 3 pelvis orientation**: 11 ± 6 degrees **Pelvis orientation at ball contact**: 6 ± 6 degrees **Kicking foot speed**: 18.2 ± 1.2 - 19.7 ± 1.3 m/s **Angle of approach**: 13 degrees **Length of final stride**: 1.60 m **Support foot distance**: 0.27 m

Langhout et al., 2015, cross-sectional[11]	Maastricht, The Netherlands, Elite asymptomatic adult male soccer players, n=20 **Mean and Standard Deviation** Age: 21.5 ± 4.0 years Height: 1.83 ± 0.07 m Body mass: 80.5 ± 8.31 kg Right footed = 18 Left footed = 2 Setting - Clinical movement lab	6 kicking events defined 5 phases of the maximal instep kick (Timing is reported) 11 peak kinematics of upper body and kicking leg segments, significantly concurred with 4 keypoints (MHE, MKF, KF90, BI) during the leg cocking and acceleration phases. TO = toe off HS = heelstrike TVI = toe velocity inflection MShE = maximal range of motion shoulder extension MAASF = maximal angular acceleration spine flexion MAAPPT = maximal angular acceleration posterior pelvic tilt MAVSF = maximal angular velocity spine flexion MAVShF = maximal angular velocity shoulder flexion MAAKE = maximal angular acceleration knee extension	**Mean and Standard Deviation Reported** **5 phases of instep kick** Preparation: 0.200 ± 0.050 s (32.9 ± 5.7%) Backswing: 0.112 ± 0.026 s (18.5 ± 3.8%) Leg cocking: 0.072 ± 0.009 s (12.2 ± 2.2%) Acceleration: 0.070 ± 0.007 s (11.7 ± 1.5%) Follow through: 0.150 ± 0.038 s (24.7 ± 5.2%) Total: 0.603 ± 0.074 s (100%) **Kicking Events** TO: 0 s (0%) HS: 0.20 ± 0.050 s (32.9 ± 5.7%) MHE: 0.31 ± 0.058 s (51.4 ± 5.0%) MKF: 0.38 ± 0.059 s (63.6 ± 5.2%) BI: 0.45 ± 0.061 s (75.2 ± 5.2%) TVI: 0.60 ± 0.074 s (100.0%) **11 Peak kinematics at 4 keypoints** **MHE: (51.4 ± 5.0%)**

		MADHF = maximal angular deceleration hip flexion MPAR = maximal range of motion pelvic anterior rotation MH deflexion = maximal hip deflexion MADPAR = maximal angular deceleration pelvic anterior rotation MADSF = maximal angular deceleration spine flexion	MShE: 49.9 ± 6.7% **MKF: (63.6 ± 5.2%)** MAASF: 63.6 ± 4.7% MAAPPT: 63.9 ± 4.7% **KF90: (69.3±4.9%)** MAVSF: 68.7 ± 4.5% MAVShF: 69.1 ± 4.9% MAAKE: 69.3 ± 5.2% MADHF: 69.6 ± 5.5% **BI: (75.2±5.2%)** MPAR: 75.4 ± 5.4% MH deflexion: 76.0 ± 5.5% MADPAR: 75.3 ± 5.2% MADSF: 75.8 ± 4.9%
Navandar et al., 2018, cross-sectional[30]	Madrid, Spain, Male (Team from Segunda Divisiòn B, n=15) and female (Team from Primera Division Feminina,	Dominant and non-dominant limbs were measured.	**Mean and Standard Deviation Reported** **F Dominant Limb Hip angles (º) and angular velocities (rad/s):**

	n=16) asymptomatic professional soccer players, n=31 **Mean and Standard Deviation** Male age: 21.16 ± 2.00 yrs Weight: 71.46 ± 6.22 kg Female age: 22.15 ± 4.50 yrs Weight: 60.71 ± 9.48 kg Setting - Artificial turf; shoes for artificial turf worn All players were deemed match fit and free of injury, however they compared previously injured (hamstring) players vs uninjured players (only data from previously uninjured players/limbs were extracted).	Hip/knee angles and angular velocities were measured at backswing, leg cocking, leg acceleration, and follow through Peak linear velocities of the ball, knee, and hip were also measured.	Backswing: -15±9 degrees and 0 rad/s Leg cocking: 12±10 degrees and 12±2 rad/s Leg acceleration: 27±11 degrees and -3±3 rad/s Follow through: 86±17 degrees and 1±2 rad/s **F Non-Dominant Limb Hip angles (º) and angular velocities (rad/s):** Backswing: -13±10 degrees and 0 rad/s Leg cocking: 14±9 degrees and 10±2 rad/s Leg acceleration: 30±9 degrees and -2±2 rad/s Follow through: 83±18 degrees and 2±3 rad/s **F Dominant Limb Knee angles (º) and angular velocities (rad/s):** Backswing: 67±19 degrees and 15±3 rad/s Leg cocking: 112±11 degrees and 0±1 rad/s Leg acceleration: 45±9 degrees and -28±5 rad/s Follow through: 26±12 degrees and 4±5 rad/s **F Non-Dominant Limb Knee angles (º) and angular velocities (rad/s):**

			Backswing: 72±14 degrees and 14±3 rad/s Leg cocking: 114±12 degrees and 0±1 rad/s Leg acceleration: 58±12 degrees and -26±4 rad/s Follow through: 26±14 degrees and 4±4 rad/s **M Dominant Limb Hip angles (º) and angular velocities (rad/s):** Backswing: -13±8 degrees and 0 rad/s Leg cocking: 15±6 degrees and 11±1 rad/s Leg acceleration: 28±9 degrees and -1±3 rad/s Follow through: 97±16 degrees and 3±2 rad/s **M Non-Dominant Limb Hip angles (º) and angular velocities (rad/s):** Backswing: -10±9 degrees and 0 rad/s Leg cocking: 16±9 degrees and 10±2 rad/s Leg acceleration: 30±10 degrees and 0±3 rad/s Follow through: 93±15 degrees and 2±3 rad/s

			M Dominant Limb Knee angles (º) and angular velocities (rad/s): Backswing: 74±10 degrees and 17±5 rad/s Leg cocking: 118±8 degrees and 0±1 rad/s Leg acceleration: 43±11 degrees and -32±4 rad/s Follow through: 27±20 degrees and 5±3 rad/s **M Non-Dominant Limb Knee angles (º) and angular velocities (rad/s):** Backswing: 72±8 degrees and 16±2 rad/s Leg cocking: 116±9 degrees and 0±1 rad/s Leg acceleration: 46±14 degrees and -28±5 rad/s Follow through: 28±16 degrees and 4±5 rad/s **Peak Ball Velocity (m/s):** F Dominant Leg: 25.25±2.47 F Non-Dominant Leg: 22.19±2.86 M Dominant Leg: 28.63±1.75 M Non-Dominant Leg: 26.06±2.78

			Peak Hip Linear Velocity (m/s): F Dominant Leg: 4.10±0.45 F Non-Dominant Leg: 3.81±0.60 M Dominant Leg: 4.38±0.62 M Non-Dominant Leg: 4.22±0.65 **Peak Knee Linear Velocity (m/s):** F Dominant Leg: 9.05±0.83 F Non-Dominant Leg: 8.33±1.06 M Dominant Leg: 10.13±0.62 M Non-Dominant Leg: 9.22±0.81
Cordeiro et al., 2012, cross-sectional[31]	Lisbon, Portugal, Asymptomatic male soccer players from the Portuguese Soccer League, (n=9) **Mean and Standard Deviation** Age: 24.0 ± 3.5 years Height: 1.76 ± 0.05 m Mass: 72.9 ± 3.5 kg Setting – Lab	Knee kinematics were analysed during the acceleration phase of the kick only. Knee flexion and extension angles at ball contact and maximum velocity instants were measured.	**Mean and Standard Deviation Reported** **Maximum knee flexion:** 93.3 ± 5.2 degrees **Maximum knee extension:** -0.1 ± 0.1 degrees **Total ROM:** 93.2 ± 5.2 degrees **Maximum Velocity:** 1,162.5 ± 129.1 degrees/s **Contact Angle:** 55.0 ± 7.5 degrees

	Previously injured (ACL reconstruction) players were compared with uninjured players (only data from the uninjured players/limbs were extracted).		**Peak Velocity Angle:** 56.9 ± 5.7 degrees
Alcock et al., 2012, cross-sectional[32]	Australia, Asymptomatic female international soccer players (n=15) **Mean and Standard Deviation** Age: 20.1 ± 3.2 years Height: 1.69 ± 0.06 m Mass: 61.6 ± 5.8 kg Left footed = 1 Right footed = 14 Setting – Artificial turf; soccer boots were worn Instep kick kinematics was compared with curve kick kinematics (only data from instep kick was extracted).	3-D Kinematics were collected for the instep kick at approach and at ball impact. Global angles (relative to laboratory – 0 degrees is pointing at the target unless otherwise stated). Relative angles (0 degrees is anatomical position).	**Mean and Standard Deviation Reported** **Approach:** **Approach Angle:** 18.0 ± 7.3 degrees **Velocity (trunk centre of mass):** 3.31 ± 0.56 m/s **Length of last stride:** 1.55 ± 0.14 m **Distance from support foot heel to ball centre (x axis):** 0.33 ± 0.07 m **Distance from support foot heel to ball centre (y axis):** 0.10 ± 0.07 m **At Impact:** 1. **Linear Joint Velocities** **Right ankle:** 15.54 ± 0.96 m/s **Right 5th metatarsal:** 17.70 ± 1.92 m/s **Right knee:** 4.09 ± 0.71 m/s

			Right hip: 1.81 ± 0.56 m/s **2. Global Angles** **Left foot abduction (-) /adduction angle (+):** 2.1 ± 16.9 degrees **Right foot abduction (+)/adduction angle (-):** 44.0 ± 13.1 degrees **Pelvis transverse rotation (+ is clockwise):** 8.2 ± 10.3 degrees **Trunk transverse rotation (+ is clockwise):** 13.5 ± 10.3 degrees **Trunk forwards flexion (+)/extension (-) (0 degrees is upright):** -5.8 ± 8.3 degrees **3. Relative Angles** **Left shoulder abduction (-)/adduction angle (+):** -48.2 ± 11.7 degrees **Right hip angle:** 35.5 ± 7.8 degrees **Right hip adduction (+)/abduction angle (-):** -21.1 + 4.3 degrees **Right knee angle:** 55.6 ± 6.6 degrees **Right ankle angle:** 31.6 ± 8.8 degrees

			Right ankle dorsiflexion (+)/plantarflexion angle (-): -28.2 + 8.6 degrees **Right ankle adduction (+)/ abduction angle (-):** -8.2 ± 7.0 degrees
Palucci Vieira et al., 2021, cross-sectional[35]	São Paulo, Brazil, Asymptomatic male soccer players from Brazilian National Second Division League team, (n=14) **Mean and Standard Deviation** Age: 18.8 ± 0.8 years Weight: 70.5 ± 5.0 kg Height: 178.7 ± 6.6 cm Pelvic segment length: 0.39 ± 0.02 m Thigh segment length: 0.45 ± 0.02 m Lower leg segment length: 0.40 ± 0.02 m Setting – Natural grass; Soccer boots were worn	Lower extremity and ball kinematics were measured 1) **Peak speed**: maximum absolute speed of a given point during the duration of the trial 2) **Impact speed**: absolute speed magnitude at impact instant 3) **Relative speed**: subtraction of the proximal to the distal endpoint speed values 4) Δ**Peak speed**: peak speed – impact speed 5) **Peak relative speed**: peak speed + Δpeak speed	**Mean and Standard Deviation Reported** **1) Peak ball speed:** 30.60 ± 1.53 m/s **CM_{Foot}-to-Ball speed ratio:** 1.47 ± 0.06 a.u. **2) Speed at Impact:** **CM_{Foot}:** 20.35 ± 0.94 m/s **Non-dominant hip:** 3.05 ± 0.70 m/s **3) Relative Speed at Impact:** **Dominant to non-dominant hip:** 0.85 ± 0.29 m/s **Knee to dominant hip:** 1.95 ± 0.95 m/s **CM_{Foot} to knee:** 15.24 ± 1.12 m/s **Non-dominant hip peak velocity:** 4.62 ± 0.88 m/s

	U20, U17, U15, U13, and U11 teams were used (data was only extracted from the U20 team)		**4) Δ Peak Speed:** **Non-dominant hip:** 1.57 ± 0.63 m/s **Dominant to non-dominant hip:** 0.69 ± 0.36 m/s **Knee to dominant hip:** 6.08 ± 0.96 m/s **CM_{Foot} to knee:** 0.29 ± 0.40 m/s **5) Peak relative speed at Impact:** **Dominant to non-dominant hip:** 2.24 ± 0.57 m/s **Knee to dominant hip:** 14.10 ± 1.16 m/s **CM_{Foot} to knee:** 15.82 ± 1.18 m/s **Peak angular velocity:** **Hip:** 4.10 ± 1.32 rad/s **Knee:** 15.60 ± 1.13 rad/s **Ankle:** 31.52 ± 4.05 rad/s

Augustus et al., 2021, cross-sectional[37]	Chichester, England, Asymptomatic male soccer players affiliated to semi-professional clubs in the English FA national league, (n=15) **Mean and Standard Deviation** Age 23.8 ± 4.0 years Mass: 79.0 ± 7.5 kg Height: 1.80 ± 0.10 m Setting - Lab	Energy transfers between 4 phases of kick: Arc formation (KFTO-SFTD) Leg cocking (SFTD-MKF) Early downswing (MKF-K90) Late downswing (K90- BCS) KFTO = kicking foot take off SFTD = support foot touchdown K90 = knee extension past 90 degrees BCS = ball contact start	**Foot velocity at BCS:** 18.6 ± 0.9 m/s **Post-strike ball velocity:** 26.3 ± 1.3 m/s **Ball to foot velocity ratio:** 1.4 ± 0.1
Barfield et al., 2002, cross-sectional[36]	North Carolina, USA, Asymptomatic male (n=2) and female (n=6) elite soccer players, n=8 Age Range: 19-22 years Female Avg Weight: 60.1 kg Female Avg Height: 164.25 cm	Maximum toe velocity of the kicking foot between SFC with the floor and BC Toe velocity at BC Mean toe velocity between SFC and BC Mean toe acceleration Ankle velocity at BC Angular velocity of the knee at BC	**Max toe velocity (m/s) ± SD** - M: 20.4 ± 1.3 - F: 18.7 ± 2.9 **BC toe velocity (m/s) ± SD** - M: 18.9 ± 1.6 - F: 16.2 ± 2.3 **Mean toe velocity (m/s) ± SD** -M: 13.9 ± 1.1 - F: 13.5 ± 2.1 **Mean toe acceleration (m/s^2) ± SD**

	Male Avg Weight: 87.32 kg Male Avg Height: 184.15 cm Setting - Lab		- M: 78.3 ± 7.6 - F: 77.2 ± 14.5 **Ankle velocity at BC (m/s) ± SD** - M: 13.8 ± 1.0 - F:11.9 ± 1.1 **Angular velocity knee at BC (rad/s) ± SD** -M: 19.4 ± 1.9 - F: 19.8 ± 4.5
Amiri-Khorasani et al. 2011, within-subjects experimental design[38]	Malaysia, Highly experienced and skilled asymptomatic male soccer players, n=5 **Mean and Standard Deviation** Age: 25.60 ± 1.14 years Mass: 80 ± 4.24 kg Height: 184.60 ± 4.49 cm Years of experience: 14.6 ± 1.67 years Setting – Lab	Maximum lower leg angular velocity (LAV) Maximum thigh angular velocity (TAV) K1 – K10 = Kick 1 through 10	**LAV: (Mean ± SD) (rad/s)** K1: 40.26 ± 0.43 K2: 40.06 ± 0.53 K3: 39.87 ± 0.50 K4: 39.5 ± 0.51 K5: 39.28 ± 0.46 K6: 39.04 ± 0.35 K7: 39.02 ± 0.29 K8: 38.81 ± 0.31 K9: 38.09 ± 0.19 K10: 37.67 ± 0.41 **TAV: (Mean ± SD) (rad/s)** K1: 18.83 ± 0.29 K2: 18.80 ± 0.25 K3: 18.74 ± 0.23 K4: 18.60 ± 0.21 K5: 18.51 ± 0.21 K6: 18.23 ± 0.19 K7:18.17 ± 0.34 K8: 18.09 ± 0.21 K9: 17.87 ± 0.08 K10: 17.67 ± 0.18

Ruscello et al., 2020, cross-sectional[33]	Rome, Italy, Asymptomatic male (Regional, n=10) and female (National, n=10) soccer players, n=20 **Mean and Standard Deviation** Males: Age: 25.3 ± 6.5 years Height: 1.80 ± 0.07 m Body mass: 76.9 ± 13.2 kg Females: Age: 19 ± 3.3 years Height: 1.64 ± 0.07 m Body mass: 58.2 ± 7.2 kg Setting – Synthetic surface soccer pitch	Stage 1 (backswing) and 2 (support leg landing): Hip extension of kicking leg Knee bending of kicking leg Extension of the supporting leg Pelvis acceleration Stage 3 (impact): Kicking leg peak acceleration Pelvis acceleration	**Stage 1 (mean ± SD; 95% CI)** **Hip extension of kicking leg (degrees):** M: -5.25 ± 6.96; 0.10, -10.61 F:-11.09 ± 13.01; -1.80,-20.40 **Knee bending of kicking leg (degrees):** M: 158.55 ± 12.26; 167.97, 149.13 F: 165.39 ± 9.09; 171.85, 165.85 **Extension of the supporting leg (degrees):** M: 127.34 ± 17.09; 140.48, 114.20 F: 123.95 ± 13.70; 133.76, 114.15 **Pelvis acceleration (g):** M: 0.74 ± 0.42; 1.06, 0.41 F: 0.68 ± 0.26; 0.86, 0.50 **Stage 2 (mean ± SD; 95% CI)** **Hip extension of kicking leg (degrees):** M: -12.10 ± 9.09; -5.11, -19.08 F: -30.74 ± 13.25; -21.26, -40.22 **Knee bending of kicking leg (degrees):** M: 84.07 ± 14.75; 95.41, 72.73 F: 84.48 ± 11.21; 92.51, 76.46 **Extension of the supporting leg (degrees):** M: 156.44 ± 7.40; 162.12, 150.75 F: 161.24 ± 5.53; 165.19, 157.27 **Pelvis acceleration (g):** M: 2.52 ± 0.82; 3.15, 1.90 F: 2.17 ± 0.32; 2.40, 1.95 **Stage 3 (mean ± SD; 95% CI)** **Kicking leg peak acceleration (m/s):** M: 11.50 ± 1.61; 12.73, 10.25 F: 11.76 ± 1.09; 12.55, 10.99 **Pelvis acceleration (g):**

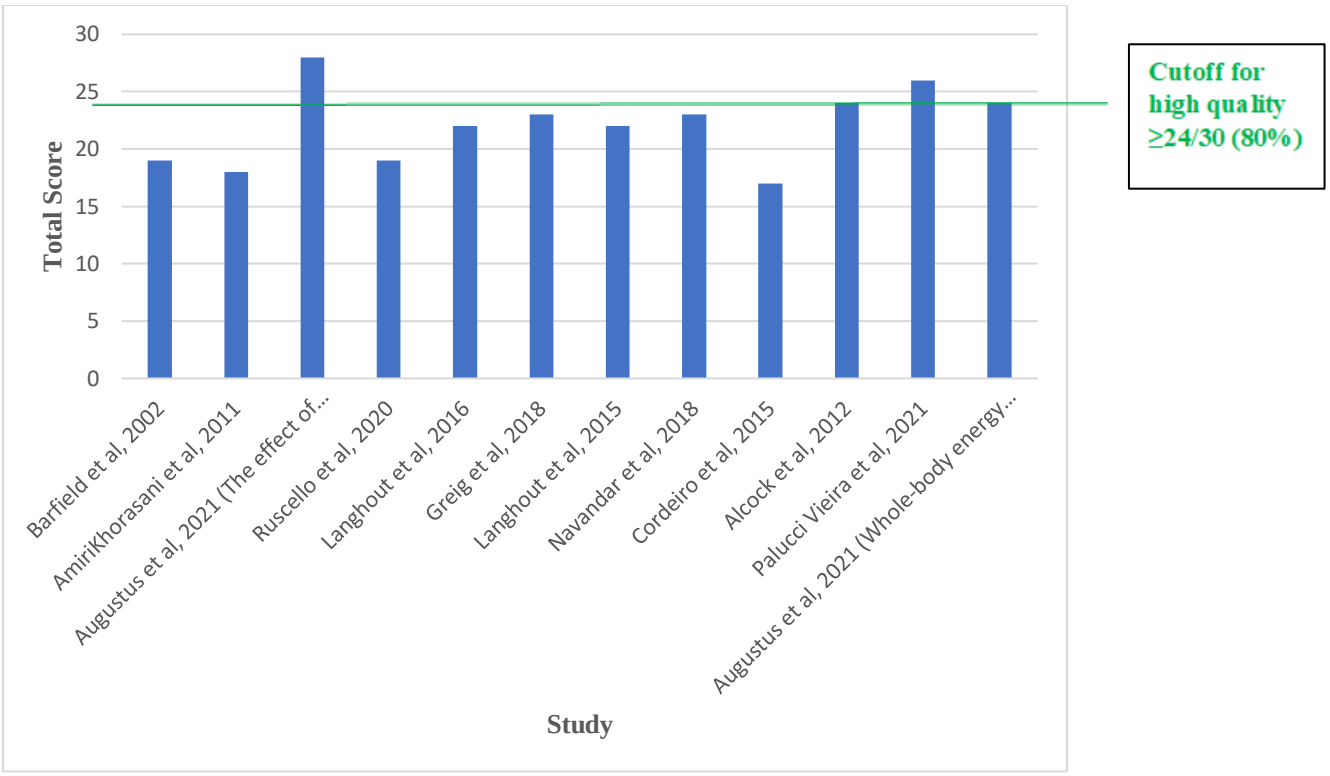
			M: 2.92 ± 1.23; 3.88, 1.99 F: 2.37 ± 0.52; 2.74, 1.99 **Ball Speed (m/s):** M: 25.88 ± 3.68; 29.56, 24.34 F: 21.87 ± 2.75; 24.64, 20.57
Augustus et al. 2021, cross-sectional[34]	West Sussex, England, Asymptomatic male soccer players affiliated to a semi-professional club within English FA national league system, n=11 **Mean and Standard Deviation** Age: 24.3 ± 4.4 years Mass: 79.9 ± 7.7 kg Height: 1.79 ± 0.06 m All players were right footed and had at least 10 years of playing experience. Setting – Clinical lab; indoor soccer shoes were worn	Kicking knee extension velocity BCS Support knee flexion ROM Peak support knee flexion angular velocity Pelvic tilt (x) ROM Pelvic transverse (z) ROM Peak pelvic tilt (x) angular velocity Peak pelvic transverse (z) angular velocity	**Mean ± SD** **Kicking knee extension velocity BCS (deg/s):** 1848 ± 272 **Support knee flexion ROM (deg):** -21.4 ± 7.4 **Peak support knee flexion angular velocity (deg/s):** -644 ± 134 **Pelvic tilt (x) ROM (deg):** 43.8 ± 3.8 **Pelvic transverse (z) ROM (deg):** 21.1 ± 5.2 **Peak pelvic tilt (x) angular velocity (deg/s):** 400 ± 57 **Peak pelvic transverse (z) angular velocity (deg/s):** 328 ± 79

Legend: ROM = range of motion, SD = standard deviation, M = male, F = female, MHE = maximal hip extension, MKF = maximal knee extension, KF90 = knee flexion 90 degrees, BI = ball impact, HF = hip flexion, SF = spine flexion, SR = spine rotation, PPT = posterior pelvic tilt, KF = knee flexion, TO = toe off, HS = heelstrike, TVI = toe velocity inflection, MShE = maximal range of motion shoulder extension, MAASF = maximal angular acceleration spine flexion, MAAPPT = maximal angular acceleration posterior pelvic tilt, MAVSF = maximal angular velocity spine flexion, MAVShF = maximal angular velocity shoulder flexion, MAAKE = maximal angular acceleration knee extension, MADHF = maximal angular deceleration hip flexion, MPAR = maximal range of motion pelvic anterior rotation, MH deflexion = maximal hip deflexion, MADPAR = maximal angular deceleration pelvic anterior rotation, MADSF = maximal angular deceleration spine flexion, KFTO = kicking foot take off, SFTD = support foot touchdown, K90 = knee extension past 90 degrees, BCS = ball contact start, SFC = support foot contact, LAV = maximum lower leg angular velocity, TAV = maximum thigh angular velocity

Risk of Bias

The methodological quality of the relevant studies is presented in Figure 2a. Four articles were deemed high quality studies[32, 34- 35, 37] while 8 were deemed not high quality studies[11, 28-31, 33, 36, 38]. Using an approach proposed by Bishop et al[22], information required to sufficiently answer Items 8, 9, 11, and 12 was not consistently provided in the articles included for review, and this was represented by a mean score of ≤1 (Figure 2b). These items included a failure to report on segment coordinate systems, model properties and degrees of freedom, axes and order of rotations, and appropriate variability/reliability/repeatability procedures, respectively. All studies reported information to sufficiently answer Items 1, 2, 3, 5, 13, and 15 (Figure 2b). These items included successful reporting on research objectives, clear study description, appropriate subject information and anthropometric details, anatomical segments being measured, main outcomes of the study, and clearly stated conclusions drawn from the study, respectively. No fatal methodological flaws were identified in any of the 12 studies. Therefore, all 12 studies were deemed relevant and were included in our data synthesis. Quality assessment scores for each individual study are demonstrated in Table 3. Three studies were funded with grants from various organizations, such as US Olympic Sports Science & Technology[36]; University Malaya Research[38]; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES), São Paulo Research Foundation (FAPESP), and National Council for Scientific and Technological Development (CNPq)[35]. Seven studies reported no conflict of interest with any financial organization[11, 28-30, 33-34, 37]. Two studies did not report about financial involvement or conflict of interest[31-32].

A



B

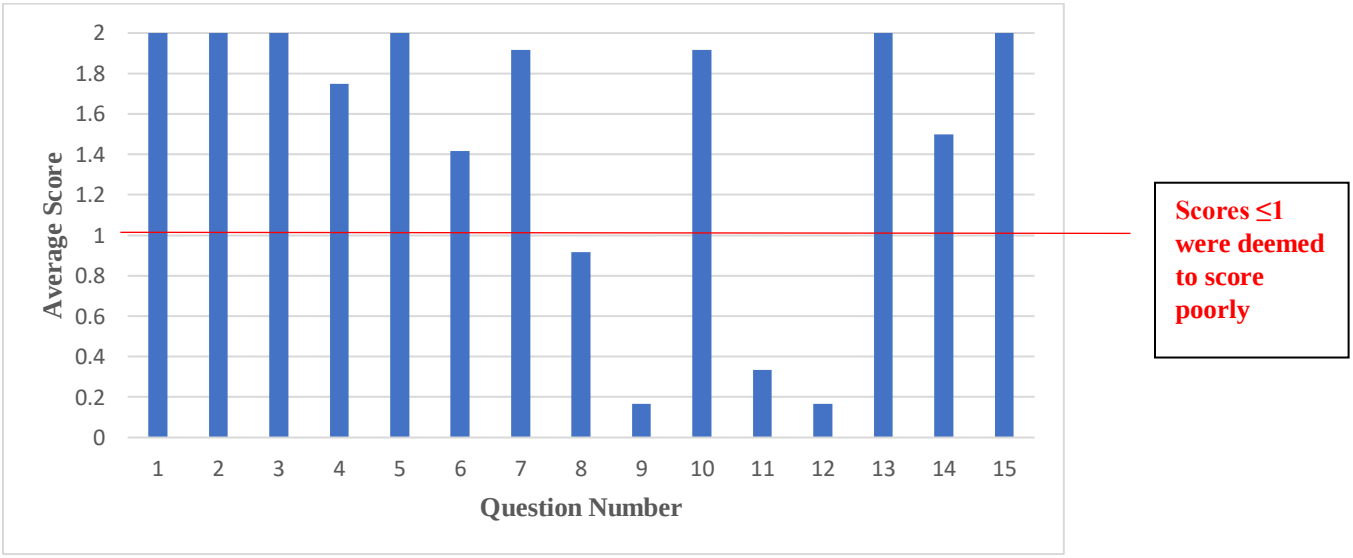


Figure 2 — Quality assessment results. (A) The average score for each article as judged by the 2 reviewers. The green line is indicative of those studies deemed high quality (ie: ≥ 24/30). The orange line is indicative of those studies deemed moderate quality (ie: between 15/30 and 23/30) (B) The average score for each question in the appraisal tool. The red line is indicative of those questions that were poorly addressed (ie: an average score ≤ 1).

Criteria	Barfield et al, 2002	AmiriKhorasani et al, 2011	Augustus et al, 2021 (The effect of approach velocity)	Ruscello et al, 2020	Langhout et al, 2016	Greig et al, 2018	Langhout et al, 2015	Navandar et al, 2018	Cordeiro et al, 2015	Alcock et al, 2012	Palucci Vieira et al, 2021	Augustus et al, 2021 (Whole-body energy transfer)
Are the research objectives or aims clearly stated?	2	2	2	2	2	2	2	2	2	2	2	2
Is the study clearly described?	2	2	2	2	2	2	2	2	2	2	2	2
Are appropriate subject information and anthropometric details provided?	2	2	2	2	2	2	2	2	2	2	2	2
Are the marker/sensors location accurately described?	1	2	2	2	2	2	2	2	0	2	2	2
Is the anatomical segment being measured clearly stated?	2	2	2	2	2	2	2	2	2	2	2	2
Is the reference position used to define anatomical frames reported?	2	0	2	0	2	2	2	1	0	2	2	2
Is the motion analysis equipment and set-up clearly described?	2	2	2	2	2	2	2	2	1	2	2	2
Are the segment coordinate systems clearly defined?	0	0	2	0	0	1	0	2	0	2	2	2
Are the model properties clearly defined for all joints (e.g. degrees of freedom?)	0	0	2	0	0	0	0	0	0	0	0	0
Were movement tasks clearly defined?	2	2	2	1	2	2	2	2	2	2	2	2
Are the methods used to describe the axes and order of rotations clearly described or referenced appropriately?	0	0	2	0	0	0	0	0	0	0	2	0
Are appropriate variability/reliablilty/repeatability procedures documented and reported?	0	0	0	0	0	0	0	0	0	2	0	0
Are the main outcomes of the study stated?	2	2	2	2	2	2	2	2	2	2	2	2
Are the limitations of the study clearly described?	0	0	2	2	2	2	2	2	2	0	2	2
Were conclusions drawn from the study clearly stated?	2	2	2	2	2	2	2	2	2	2	2	2
Is there a fatal methodological flaw identified in the study?	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SUM OF SCORES OUT OF 30	**19**	**18**	**28**	**19**	**22**	**23**	**22**	**23**	**17**	**24**	**26**	**24**

Table 3 – Quality assessment scores of included studies.

Preparation Phase

Sequential Timing of Events

The preparation phase is defined as the period between kicking leg heel-strike (HS) and kicking leg toe-off (TO)[8, 11]. HS is considered the initiation of the kick and occurs at time zero. The preparation phase is reported to occur over the span of 0.200 ± 0.050 s, and accounts for 32.9 ± 5.7% of the total duration of the kick[11]. This phase occupies the largest amount of time compared to other phases of the kick[11]. No timing sequences were reported in elite female studies.

Anatomical Positioning and Range of Motion

The angle of approach has been reported to be 13 degrees in elite men[29] and 18.0 ± 7.3 degrees in elite women[32]. In women, the length of the last stride was 1.55 ± 0.14 m, with the distance from support foot heel to ball centre being 0.33 ± 0.07 m in the x-axis and 0.10 ± 0.07 m in the y-axis[32]. In men, the length of the final stride was reported to be 1.60 m., with support foot distance measured at 0.27 m [29].

Anatomical Angular and Linear Velocities

The velocity of the trunk's centre of mass during approach was reported to be 3.31 ± 0.56 m/s in elite women[32]. This measurement was not reported in men.

Backswing Phase

Sequential Timing of Events

The backswing phase is defined as the period between TO and kicking leg maximal hip extension (MHE)[8, 11]. This period is reported to occur over the span of 0.112 ± 0.026 s. The backswing phase accounts for 18.5 ± 3.8% of the total duration of the kick[11]. MHE is reported to occur at 0.31 ± 0.058 s from the initiation of the kick (HS), which is equivalent to 51.4 ± 5.0% of

the entire sequence[11]. There is one peak kinematic that occurs during this phase – maximal range of motion shoulder extension (MShE). This event occurs at 49.9 ± 6.7% from HS. No timing sequences were reported in elite female studies.

Anatomical Positioning and Range of Motion

In elite men kicking with their dominant foot, MHE was reported to range from -12.10 ± 9.09 to -31.8 ± 6.0 degrees[28, 30, 33]. Kicking knee angle was reported to range from 63.8 ± 11.5 to 74 ± 10 degrees[28, 30]. Spinal flexion was reported to be -3.8 ± 7.2 degrees[28] and spinal rotation as -21.4 ± 6.6 degrees[28], indicating rotation to the non-kicking side. Posterior pelvic tilt was reported to be -19.5 ± 6.8 degrees, indicating pelvis anterior tilt[28].

In elite women kicking with their dominant foot, MHE was reported to range from -11.09 ± 13.01 to -15 ± 9 degrees[30, 33]. Kicking knee angle was reported to be 67 ± 19 degrees[30]. No other kinematic characteristics were reported.

Anatomical Angular and Linear Velocities

In both elite men and women kicking with their dominant feet, kicking hip angular velocity was reported to be 0 rad/s at MHE[30]. Peak hip linear velocities were reached in this phase and will be reported in the following paragraphs.

In elite men kicking with their dominant foot, kicking knee angular velocity was reported to be 17 ± 5 rad/s [30] and pelvis acceleration reported to be 0.74 ± 0.42 g [33]. Peak kicking hip linear velocity was reported to be 4.38 ± 0.62 m/s [30]. Peak support-leg hip linear velocity was reported to be however peak support-leg hip velocity was reported to be 4.62 ± 0.88 m/s [35].

In elite women kicking with their dominant foot, kicking knee angular velocity was reported to be 15 ± 3 rad/s [30] and pelvis acceleration reported to be 0.68 ± 0.26 g [33]. Peak hip linear velocity was reported to be 4.10 ± 0.45 m/s [30].

Limb Cocking Phase

Sequential Timing of Events

The limb cocking phase is defined as the period between MHE and kicking leg maximal knee flexion (MKF) [8, 11]. This period is reported to occur over the span of 0.072 ± 0.009 s [11]. The limb cocking phase accounts for 12.2 ± 2.2% of the total duration of the kick, occupying the second shortest amount of time compared to the other phases of the kick[11]. MKF is reported to occur at 0.38 ± 0.059 s from the initiation of the kick (HS), which is equivalent to 63.6 ± 5.2% of the entire sequence[11]. There are two peak kinematics that occur relative to MKF – maximal angular acceleration spine flexion (MAASF) and maximal angular acceleration posterior pelvic tilt (MAAPPT). These occur at 63.6 ± 4.7% and 63.9 ± 4.7% respectively, from the initiation of the kick (HS)[11]. No timing sequences were reported in elite female studies.

Anatomical Positioning and Range of Motion

In elite men kicking with their dominant foot, MKF was reported to range from 111.8 ± 7.1 to 158.55 ± 12.26 degrees[28, 30, 33]. Kicking hip angle was reported to range from -7.1 ± 8.8 to 15 ± 6 degrees[28, 30, 33]. Spinal flexion was reported to be 2.1 ± 8.9 degrees[28] and spinal rotation as -14.1 ± 23.9 degrees[28], indicating rotation to the non-kicking side. Posterior pelvic tilt was reported to be -4.7 ± 5.2 degrees, indicating pelvis anterior tilt[28]. Supporting leg extension was reported to be 156.44 ± 7.40 degrees[33]. Touchdown pelvic orientation was reported to be 21.5 ± 8 degrees[29] in the frontal plane, indicating rotation toward the kicking side.

In elite women kicking with their dominant foot, MKF was reported to range from 112 ± 11 degrees to 165.39 ± 9.09 degrees[30, 33]. Kicking hip angle was reported to be 12 ± 10 degrees[33]. Supporting knee extension was reported to be 161.24 ± 5.53 degrees[33]. No other kinematic characteristics were reported.

Anatomical Angular and Linear Velocities

In both elite men and women kicking with their dominant feet, kicking knee angular velocity was reported to be 0 ± 1 rad/s at MKF[30].

In elite men kicking with their dominant foot, kicking hip angular velocity was reported to range between 4.10 ± 1.32 rad/s and 11 ± 1 rad/s [30, 35]. Pelvis acceleration was reported to be 2.52 ± 0.82 g [33].

In elite women kicking with their dominant foot, kicking hip angular velocity was reported to be 12 ± 2 rad/s [30] and pelvis acceleration reported to be 2.17 ± 0.32 g [33].

Acceleration Phase

Sequential Timing of Events

The acceleration phase is defined as the period between MKF and ball impact (BI)[8, 11]. This period is reported to occur over the span of 0.070 ± 0.007 s [11]. The acceleration phase accounts for 11.7±1.5% of the total duration of the kick[11]. This phase occupies the shortest amount of time compared to other phases of the kick[11]. There are two key events that occur in this phase. The first event is knee flexion 90º (KF90) and the second event is BI.

KF90 occurs at 69.3 ± 4.9% of the entire sequence of the kick and has four peak kinematics that occur relative to it - maximal angular velocity spine flexion (MAVSF), maximal angular velocity shoulder flexion (MAVShF), maximal angular acceleration knee extension (MAAKE), and maximal angular deceleration hip flexion (MADHF). These occur respectively at 68.7 ± 4.5%, 69.1 ± 4.9%, 69.3 ± 5.2%, and 69.6 ± 5.5% from initiation of the kick (HS)[11].

BI is reported to occur at 0.45 ± 0.061 s from the initiation of the kick (HS), which is equivalent to 75.2 ± 5.2% of the entire sequence[11]. There are four peak kinematics that occur relative to BI –maximal range of motion pelvic anterior rotation (MPAR), maximal hip

deflexion, maximal angular deceleration pelvic anterior rotation (MADPAR), and maximal angular deceleration spine flexion (MADSF). These occur respectively at 75.4 ± 5.4%, 76.0 ± 5.5%, 75.3 ± 5.2%, and 75.8 ± 4.9% from initiation of the kick (HS)[11]. No timing sequences were reported in elite female studies.

Anatomical Positioning and Range of Motion

The data reported in this section will be divided into two key events – KF90 and BI:

KF90:

In elite men kicking with their dominant foot, kicking hip flexion was reported to range between 6.7 ± 9.8 and 28 ± 9 degrees[28, 30]. Kicking thigh range of motion (ROM) displacement was reported to be 32 ± 10 degrees[29]. Spinal flexion was reported to be 24.2 ± 10.9 degrees[28] and spinal rotation as 4.3 ± 7.1 degrees[28], indicating rotation towards the kicking side. Posterior pelvic tilt was reported to be 9.0 ± 7.3 degrees[28]. Pelvic orientation in the frontal plane was reported to range between 19 ± 7 and 11 ± 6 degrees[29], indicating rotation toward the kicking side. In elite women kicking with their dominant foot, kicking hip flexion was reported to be 27 ± 11 degrees[30].

BI:

In elite men kicking with their dominant foot, kicking hip flexion was reported to range between 6.4 ± 11.1[28] and 28 ± 9 degrees[30] at ball impact. Kicking knee flexion was reported to range between 35.3 ± 10.0 and 55.0 ± 7.5 degrees[28, 30-31] at ball impact. Spinal flexion was reported to be 41.4 ± 8.8 degrees[28] and spinal rotation as 12.4 ± 6.3 degrees[28], indicating rotation towards the kicking side. Posterior pelvic tilt was reported to range between 29.5 ± 5.1 and 43.8 ± 3.8 degrees[28, 34]. Pelvic orientation in the frontal plane was reported to be 6 ± 6 degrees[29], indicating rotation toward the kicking side. Pelvic orientation in the transverse plane was

reported to be 21.1 ± 5.2 degrees[34], indicating rotation toward the kicking side. Support knee flexion was reported to be 21.4 ± 7.4 degrees[34]. Shank ROM displacement was reported to range between 64 ± 11 degrees and 93.2 ± 5.2 degrees[29, 31] during Stage 3, which is distinguished as the time period beginning from shank angular velocity increase up to the instant of ball contact. The knee angle at which peak knee velocity occurred was reported to be at 56.9 ± 5.7 degrees[31].

In elite women kicking with their dominant foot, kicking hip flexion was reported to range between 27 ± 11 degrees and 35.5 ± 7.8 degrees[30, 32], with hip abduction reported to be 21.1 + 4.3 degrees[32]. Kicking knee flexion was reported to range between 45 ± 9 degrees and 55.6 ± 6.6 degrees[30, 32]. Relative kicking ankle angles (in relation to the shank) were reported as follows – plantarflexion: 28.2 + 8.6 degrees, abduction: 8.2 ± 7.0 degrees, and transverse plane rotation: 31.6 ± 8.8 degrees[32]. The global kicking foot angle (in relation to the kicking target) was reported to be 44.0 ± 13.1 degrees in abduction[32]. The global support-foot angle (in relation to the kicking target) was reported to be 2.1 ± 16.9 degrees in adduction[32]. Other global angles were reported as follows – pelvis transverse rotation: 8.2 ± 10.3 degrees clockwise, trunk transverse rotation: 13.5 ± 10.3 degrees clockwise, and trunk extension: 5.8 ± 8.3 degrees[32]. The angle of the shoulder opposite to the kicking foot was reported to be 48.2 ± 11.7 degrees in abduction[32].

Anatomical Angular and Linear Velocities

In elite men kicking with their dominant foot, kicking hip angular velocity was reported to be 1 ± 3 rad/s during the acceleration phase[30]. Kicking knee angular velocity was reported to range between 15.60 ± 1.13 rad/s and 32 ± 4 rad/s during the acceleration phase[30-31, 34-36, 38]. Peak knee linear velocity was reached in this stage and was reported to be 10.13 ± 0.62 m/s [30]. Ankle velocity at BI was reported to be 13.8 ± 1.0 m/s [36]. Peak ankle angular velocity was reached in

this stage and was reported to be 31.52 ± 4.05 rad/s [35]. Foot velocity at BI was reported to range from 18.2 ± 1.2 to 20.35 ± 0.94 m/s [29, 35, 37]. Toe velocity at BI was reported to be 18.9 ± 1.6 m/s [36]. Max toe velocity was reached during the acceleration phase before BI and was reported to be 20.4 ± 1.3 m/s [36]. Pelvis acceleration was reported to be 2.92 ± 1.23 g at BI[33]. Support-leg hip velocity at BI was reported to be 3.05 ± 0.70 m/s [35].

In elite women kicking with their dominant foot, kicking hip angular velocity was reported to be 3 ± 3 rad/s during the acceleration phase[30]. Hip linear velocity was reported to be 1.81 ± 0.56 m/s at BI[32]. Kicking knee angular velocity was reported to range between 19.8 ± 4.5 rad/s and 28 ± 5 rad/s during the acceleration phase[30, 36]. Peak knee linear velocity was reached in this stage and was reported to be 9.05 ± 0.83 m/s [30]. At BI, knee linear velocity was reported to be 4.09 ± 0.71 m/s [32]. Ankle velocity at BI was reported to range between 11.9 ± 1.1 m/s and 15.54 ± 0.96 m/s [32, 36]. Foot velocity at BI was reported to be 17.70 ± 1.92 m/s [32]. Toe velocity at BI was reported to be 16.2 ± 2.3 m/s [36]. Max toe velocity was reached during the acceleration phase before BI and was reported to be 18.7 ± 2.9 m/s [36]. Pelvis acceleration was reported to be 2.37 ± 0.52 g at BI[33].

Follow-Through Phase

Sequential Timing of Events

The follow-through phase is defined as the period between BI and kicking limb toe velocity inflection (TVI)[8, 11]. This period is reported to occur over the span of 0.150 ± 0.038 s [11]. The follow-through phase accounts for 24.7 ± 5.2% of the total duration of the kick, occupying the second largest amount of time compared to the other phases of the kick[11]. TVI is reported to occur at 0.60 ± 0.074 s from the initiation of the kick (HS) and indicates the concluding event of the entire kicking sequence[11]. No timing sequences were reported in elite female studies.

Anatomical Positioning and Range of Motion

In elite men kicking with their dominant foot, kicking hip flexion was reported to be 97 ± 16 degrees at the end of follow-through[30]. Kicking knee angle was reported to be 27 ± 20 degrees[30]. Follow through maximum knee extension was reported to be -0.1 ± 0.1 degrees[31].

In elite women kicking with their dominant foot, kicking hip flexion was reported to be 86 ± 17 degrees[30]. Kicking knee angle was reported to be 26 ± 12 degrees[30].

Anatomical Angular and Linear Velocities

In elite men kicking with their dominant foot, hip angular velocity was reported to be 3 ± 2 rad/s [30] at the end of follow-through. Kicking knee angular velocity was reported to be 5 ± 3 rad/s [30]. Ball speed was reported to range between 25.88 ± 3.68 m/s (93.168 km/h) and 98.8 ± 9.0 km/h (27.444 m/s)[28, 30, 33, 35, 37].

In elite women kicking with their dominant foot, hip angular velocity was reported to be 1 ± 2 rad/s [30]. Kicking knee angular velocity was reported to be 4 ± 5 rad/s [30]. Ball speed was reported to range between 21.87 ± 2.75 m/s and 25.25 ± 2.47 m/s [30,33].

DISCUSSION

Until now, there have been no known published systematic reviews conducted on the topic of whole-body kinematic description of the instep kicking technique in elite adult soccer players. Previous narrative reviews have utilized general populations of soccer players from all levels and ages, without stratification[3,12,13]. The focus of this review was to kinematically quantify the skill of maximal effort instep kicking in elite-level soccer players over the age of 18, through its entirety of movement. The instep kicking skill is characterized by 5 distinct phases: preparation, backswing, limb cocking, acceleration, and follow-through[8]. In all the studies synthesized, coordinated proximal to distal sequencing of the kick leg during the downswing was observed in

all elite athletes[11, 28-38]. This sequencing is characteristic, in which hip flexor muscles accelerate the hip first and subsequently knee extensor muscles accelerate the knee. Good inter-limb coordination and an inter-segmental transfer of energy are required for this process. Furthermore, eccentric formation and concentric release of a 'tension arc' between the torso, pelvis and kicking hip were observed. The formation of the 'tension arc' included torso extension and transverse rotation to non-kick side, as well as kicking hip extension to maximise eccentric pre-tensioning and stability of anterior lumbo-pelvic and hip muscles. Pelvis posterior rotation at the kickside, pelvis anterior tilt and shoulder extension at the non-kickside were also key kinematics in the formation of the 'tension arc'. Release of the 'tension arc' included torso flexion and transverse rotation to kick leg side, as well as kick leg hip flexion and adduction to maximise simultaneous concentric work. Additionally, pelvis anterior rotation, knee extension at the kickside, pelvis posterior tilt, and shoulder flexion to the kickside were key components of 'release'.

Overall, qualitative descriptions from this systematic review generally overlap previous narrative reviews. Concepts such as the eccentric formation and concentric release of the 'tension arc', the sequencing of the 5 distinct kinematic phases of the kick, and important peak velocity events found during the acceleration phase of the kick, are all reiterated in this study. However, precise quantitative measurements were never addressed in the previous reviews. This systematic review was able to quantify specific timing, positional, and velocity numerical data from a population of professional athletes over the age of 18. These numerical data help to better illustrate the anatomical positioning and speeds related to the skill of instep kicking at the elite level.

Differences were observed between elite men and women, although they were small. These data are consistent with data reported in previous narrative reviews[3,12,13]. Men were reported to have a greater average ball speed than women[28, 30, 33, 35, 37]. Many ROM kinematic variables investigated were either within a similar range between men and women, or slightly lower in women compared to men[28-34, 36]. The only variables that were observed to be slightly larger in women than in men were MKF and hip flexion at BI[28, 30, 32]. With relation to angular and linear velocities/accelerations, most kinematic variables investigated were either slightly greater in men compared to women, or within the same range[30-33, 35-36, 38]. The only variable that was observed to be slightly larger in women than in men was kicking hip angular velocity during limb cocking and acceleration phases[30]. All other acceleration phase velocities were greater in men compared to women[30-33, 35-36, 38].

A concept that had not been considered in previous narrative reviews pertains to the appraisal of methodological quality of the studies included in the analyses. Due to the systematic nature of this review, we were able to critically evaluate the methodological quality of the included studies using a modified kinematic study assessment tool[22-24]. Our appraisal determined that although none of the included kinematic studies comprised of any fatal methodological flaws, the majority of included kinematic studies were not able to consistently address 4 criteria in our assessment tool. These criteria included a failure to report on segment coordinate systems, model properties and degrees of freedom, axes and order of rotations, and appropriate variability/reliability/repeatability procedures. From this analysis, we strongly suggest that all future kinematic studies remember to incorporate these 4 important features to address and report in their methods. All studies in this review, however, successfully reported information to sufficiently answer criteria related to reporting on research objectives, clear study descriptions,

appropriate subject information and anthropometric details, anatomical segments being measured, main outcomes of the study, and clearly stated conclusions drawn from the study.

Some limitations exist for this review. Due to the heterogeneity of studies, a meta-analysis was not performed on the data extracted. Also, only studies published in peer-review journals were reviewed in this study, and as in other reviews, a publication bias may have occurred. Furthermore, only the kinematics of elite male and female adult soccer players were assessed in this review. Future reviews can evaluate the kicking kinematics of sub-elite and amateur soccer players, as well as those aged younger than 18 years of age. More research is needed to gather further data on elite female instep kick kinematics. Moreover, future original research studies can investigate the practical effects of enhancing kick kinematics either through specific training methods or other interventions.

CONCLUSION

The results of this review descriptively demonstrate important kinematic characteristics related to timing, body positioning/coordination, and anatomical angular/linear velocities in elite adult soccer player instep kicking. None of the included 12 studies demonstrated any major methodological flaws. Improved scientific and kinematic data collection methods are necessary in future studies – specifically in achieving better reporting on segment coordinate systems, model properties and degrees of freedom, axes and order of rotations, and appropriate variability/reliability/repeatability procedures. Further studies investigating the elite adult soccer player population will help to develop a better understanding of maximal instep soccer kick kinematics.

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Appendix 1. Ovid MEDLINE search strategy

Database and Platform: Ovid MEDLINE(R) ALL <Inception to present (2022)>

Search Strategy:

1. Biomechanical Phenomena/
2. Movement/
3. Task Performance and Analysis/
4. Range of Motion, Articular/
5. Lower Extremity/ physiology
6. Knee/ physiology
7. Foot/ physiology
8. Hip/ physiology
9. Leg/ physiology
10. Exercise/ physiology
11. Muscle, Skeletal/ physiology
12. Running/ physiology
13. Psychomotor Performance/ physiology
14. Athletic Performance/ physiology
15. Time Factors/
16. Electromyography/
17. Muscle Strength/
18. Motor Activity/
19. Adaptation, Physiological/
20. Acceleration/
21. Kinetics/
22. Energy Transfer/
23. Motor Skills/
24. Time and Motion Studies/
25. Stress, Mechanical/
26. Models, Biological/
27. Torque/
28. Rotation/
29. Computer Simulation/
30. Muscle Contraction/
31. Postural Balance/
32. Functional Laterality/
33. Motion/
34. exp Acceleration/
35. Imaging, Three Dimensional/
36. Efficiency/
37. biomechanic*.mp.
38. movement*.mp.

39. task* adj3 performanc*.mp.
40. task* adj3 analy*.mp.
41. “range of motion”.mp.
42. lower adj2 (extremit* adj3 physiolog*).mp.
43. knee adj3 physiolog*.mp.
44. foot adj3 physiolog*.mp.
45. hip adj3 physiolog*.mp.
46. leg adj3 physiolog*.mp.
47. kick* adj3 physiolog*.mp.
48. athlet* adj3 performance*.mp.
49. time* adj3 factor*.mp.
50. biolog* adj3 model*.mp.
51. electromyograph*.mp.
52. muscle* adj3 strength*.mp.
53. motor* adj3 activit*.mp.
54. kinetic*.mp.
55. energy* adj3 transfer.mp.
56. motor* adj3 skill*.mp.
57. mechanic*.mp.
58. torque*.mp.
59. rotation*.mp.
60. muscl* adj3 contract*.mp.
61. postur* adj3 balanc*.mp.
62. function* adj3 lateralit*.mp.
63. motion*.mp.
64. efficien*.mp.
65. procedur*.mp.
66. segment* adj3 joint*.mp.
67. backswing* or back-swing* or back adj2 swing*).mp.
68. accelerat*.mp.
69. decelerat*.mp.
70. adductor*.mp.
71. contact* adj3 (foot-to-ball* or foot-ball*).mp.
72. velocit*.mp.
73. (biophysic* or bio-physic*).mp.
74. techn* adj3 analy*.mp.
75. kinematic*.mp.
76. 1-75/ OR
77. Soccer/
78. football*.mp.
79. soccer*.mp.
80. futbol*.mp.
81. 77-80/ OR

82. kick*.mp.
83. shoot*.mp.
84. 82-83/ OR
85. 76 AND 81 AND 84
86. Soccer/ physiology/
87. 86 AND 88
88. 85 OR 87
89. (comment or clinical conference or congress or consensus development conference or editorial or letter or review or systematic review or guideline or practice guideline or case reports).pt.
90. 88 NOT 89
91. Animals/
92. Humans/
93. 91 NOT 92
94. 90 NOT 93

CINAHL search strategy

Database & Platform: CINAHL (EBSCO) <Inception to present (2022)>

Search strategy:

1. MH Biomechanics +
2. MH Movement
3. MH Task Performance and Analysis
4. MH Range of Motion
5. MH Exercise Physiology
6. MH Lower Extremity/PH
7. MH Knee/PH
8. MH Foot/ PH
9. MH Hip/ PH
10. MH Leg/
11. MH Exercise/ PH
12. MH Muscle, Skeletal/ PH
13. MH Running/ PH
14. MH Psychomotor Performance
15. MH Athletic Performance/ PH
16. MH Time Factors
17. MH Electromyography
18. MH Muscle Strength
19. MH Motor Activity
20. MH Adaptation, Physiological
21. MH Acceleration (Physiology)
22. MH Acceleration (Mechanics)
23. MH Kinetics
24. MH Energy Transfer
25. MH Motor Skills
26. MH Time and Motion Studies
27. MH Stress, Mechanical
28. MH Models, Biological
29. MH Torque
30. MH Rotation
31. MH Computer Simulation
32. MH Muscle Contraction +
33. MH Balance, Postural
34. MH Motion
35. MH Imaging, Three Dimensional
36. TI biomechanic* or AB biomechanic*
37. TI movement* or AB movement*
38. TI task* n3 performance* or AB task* n3 performance*

39. TI task* n3 analy* or AB task* n3 analy*
40. TI “range of motion” or AB “range of motion”
41. TI lower adj2 (extremit* n3 physiolog*) or AB lower adj2 (extremit* n3 physiolog*)
42. TI knee n3 physiolog* or AB knee n3 physiolog*
43. TI foot n3 physiolog* or AB foot n3 physiolog*
44. TI hip n3 physiolog* or AB hip n3 physiolog*
45. TI leg n3 physiolog* or AB leg n3 physiolog*
46. TI kick* n3 physiolog* or AB kick* n3 physiolog*
47. TI athlet* n3 performance* or AB athlet* n3 performance*
48. TI time* n3 factor* or AB time* n3 factor*
49. TI biolog* n3 model* or AB biolog* n3 model*
50. TI electromyograph* or AB electromyograph*
51. TI muscle* n3 strength* or AB muscle* n3 strength*
52. TI motor* n3 activit* or AB motor* n3 activit*
53. TI kinetic* or AB kinetic*
54. TI energy* n3 transfer or AB energy* n3 transfer
55. TI motor* n3 skill* or AB motor* n3 skill*
56. TI mechanic* or AB mechanic*
57. TI torque* or AB torque*
58. TI rotation* or AB rotation*
59. TI muscl* n3 contract* or AB muscl* n3 contract*
60. TI postur* n3 balanc* or AB postur* n3 balanc*
61. TI function* n3 lateralit* or AB function* n3 lateralit*
62. TI motion* or AB motion*
63. TI efficien* or AB efficien*
64. TI procedur* or AB procedur*
65. TI segment* n3 joint* or AB segment* n3 joint*
66. TI backswing* or AB backswing*
67. TI plan* n3 movement or AB plan* n3 movement
68. TI accelerat* or AB accelerat*
69. TI decelerat* or AB decelerat*
70. TI angular* n3 velocit* or AB angular* n3 velocit*
71. TI adductor* or AB adductor*
72. TI contact* n3 (foot-to-ball* or foot-ball*) or AB contact* n3 (foot-to-ball* or foot-ball*)
73. TI ball n3 velocit* or AB ball n3 velocit*
74. TI (biophysic* or bio-physic*) or AB (biophysic* or bio-physic*)
75. TI techn* n3 analy* or AB techn* n3 analy*
76. TI kinematic* or AB kinematic*
77. 1-76/ OR
78. Soccer/
79. TI soccer* or AB soccer*
80. TI football* or AB football*
81. TI futbol* or AB futbol*

82. 78-81/ OR
83. kick* or AB
84. shoot* or AB
85. 83-84/ OR
86. 77 AND 82 AND 85
87. Soccer/PH
88. 85 AND 87
89. 86 OR 88
90. 89 NOT PT (abstract or brief item or book review or case study or commentary or doctoral dissertation or editorial or letter or practice guidelines or proceedings or review or systematic review)
91. MH Animals
92. MH Human
93. 91 NOT 92
94. 90 NOT 93

SPORTDISCUS search strategy

Database & Platform: SportDiscus (EBSCO) <Inception to present (2022)>

Search strategy:

1. DE Biomechanics
2. DE Biomechanics in sports
3. DE Biophysics
4. DE Movement sequences
5. DE Range of Motion of joints
6. DE Exercise Physiology
7. DE Knee physiology
8. DE Foot physiology
9. DE Hip joint physiology
10. DE Leg Physiology
11. DE Leg Muscle Physiology
12. DE Muscle contraction
13. DE Running
14. DE Electromyography
15. DE Muscle Strength
16. DE Physiological adaptation
17. DE Acceleration (Physiology)
18. DE Acceleration (Mechanics)
19. DE Dynamics
20. DE Motor Ability
21. DE Biological Models
22. DE Torque
23. DE Motion
24. DE Kinematics
25. DE Kinematics in sports
26. DE Physiological Stress
27. DE Biological Models
28. DE Postural balance
29. DE Motorsoccer
30. TI biomechanic* or AB biomechanic*
31. TI movement* or AB movement*
32. TI task* n3 performance* or AB task* n3 performance*
33. TI task* n3 analy* or AB task* n3 analy*
34. TI “range of motion” or AB “range of motion”
35. TI lower adj2 (extremit* n3 physiolog*) or AB lower adj2 (extremit* n3 physiolog*)
36. TI knee n3 physiolog* or AB knee n3 physiolog*
37. TI foot n3 physiolog* or AB foot n3 physiolog*
38. TI hip n3 physiolog* or AB hip n3 physiolog*

39. TI leg n3 physiolog* or AB leg n3 physiolog*
40. TI kick* n3 physiolog* or AB kick* n3 physiolog*
41. TI athlet* n3 performance* or AB athlet* n3 performance*
42. TI time* n3 factor* or AB time* n3 factor*
43. TI biolog* n3 model* or AB biolog* n3 model*
44. TI electromyograph* or AB electromyograph*
45. TI muscle* n3 strength* or AB muscle* n3 strength*
46. TI motor* n3 activit* or AB motor* n3 activit*
47. TI kinetic* or AB kinetic*
48. TI energy* n3 transfer or AB energy* n3 transfer
49. TI motor* n3 skill* or AB motor* n3 skill*
50. TI mechanic* or AB mechanic*
51. TI torque* or AB torque*
52. TI rotation* or AB rotation*
53. TI muscl* n3 contract* or AB muscl* n3 contract*
54. TI postur* n3 balanc* or AB postur* n3 balanc*
55. TI function* n3 lateralit* or AB function* n3 lateralit*
56. TI motion* or AB motion*
57. TI efficien* or AB efficien*
58. TI procedur* or AB procedur*
59. TI segment* n3 joint* or AB segment* n3 joint*
60. TI backswing* or AB backswing*
61. TI plan* n3 movement or AB plan* n3 movement
62. TI accelerat* or AB accelerat*
63. TI decelerat* or AB decelerat*
64. TI angular* n3 velocit* or AB angular* n3 velocit*
65. TI adductor* or AB adductor*
66. TI contact* n3 (foot-to-ball* or foot-ball*) or AB contact* n3 (foot-to-ball* or foot-ball*)
67. TI ball n3 velocit* or AB ball n3 velocit*
68. TI (biophysic* or bio-physic*) or AB (biophysic* or bio-physic*)
69. TI techn* n3 analy* or AB techn* n3 analy*
70. TI kinematic* or AB kinematic*
71. 1-70/ OR
72. DE Soccer
73. DE Indoor Soccer
74. TI soccer* or AB soccer*
75. TI football* or AB football*
76. TI futbol* or AB futbol*
77. 72-76/ OR
78. kick* or AB
79. shoot* or AB
80. 78-79/ OR
81. 71 AND 77 AND 80

82. 81 NOT PT (commentary or letter or editorial or review or case study)
83. SU conferences
84. 82 NOT 83

Appendix 2. References of Studies That Were Excluded at Full Text Screening

Studies Excluded Due to Ineligible Population

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