# Are wearable technologies accurate enough to assessment of soccer kicking: Protocol for a systematic literature review

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## *Abstract*

**Background:** Wearable technology is widely applied in performance monitoring, an integral part of sports and exercise sciences. The kick movement in soccer exemplifies a sports technique that could benefit from appropriate biomechanics assessment methodologies. However, the accuracy of wearables in quantifying soccer kick mechanics, particularly under field conditions, remains unclear.

**Objective:** This article presents a protocol for a systematic review to discuss the measurement properties (validity, reliability and/or measurement error aspects) of wearable technology systems explicitly used to measure ball-kicking features in soccer.

**Methods:** This review protocol was pre-registered in the Open Science Framework. Two authors will perform searches in major electronic databases: MEDLINE, Physical Therapy and Sports Medicine, Web of Science, ProQuest, IEEE Xplore, EBSCOHost, and Scopus. Following a specific PICO framework, studies will be screened based on predetermined inclusion and exclusion criteria. The methodological quality of the included studies will be assessed using the COSMIN checklist. Data extraction will be conducted to determine the level of evidence according to the "best evidence synthesis method."

**Results:** This ongoing systematic review has completed database searches and is currently in the screening phase. Depending on the number and consistency of studies, results may be presented via meta-analysis or qualitative synthesis, with sub-group analyses considering factors like gender, age, and playing level. The final results are expected by May 2024, with manuscript submission anticipated by August 2024.

**Conclusions:** Our study will provide a comprehensive summary of the highest level of evidence available on the use of wearables for the assessment of soccer kick mechanics, providing practical guidance for athletes and sports sciences professionals regarding the validity, reliability and/or measurement error aspects of using wearable technology to measure ball-kicking features in soccer. Clinical Trial: Open Science Framework (OSF) – repository under Registry ID: https://osf.io/zm3j6

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## Protocol

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## Abstract

**Background:** Wearable technology is widely applied in performance monitoring, an integral part of sports and exercise sciences. The kick movement in soccer exemplifies a sports technique that could benefit from appropriate biomechanics assessment methodologies. However, the accuracy of wearables in quantifying soccer kick mechanics, particularly under field conditions, remains unclear.
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**Conclusions:** Our study will provide a comprehensive summary of the highest level of evidence available on the use of wearables for the assessment of soccer kick mechanics, providing practical guidance for athletes and sports sciences professionals regarding the validity, reliability and/or measurement error aspects of using wearable technology to measure ball-kicking features in soccer.
**Trial Registration:** Open Science Framework (OSF) – repository under Registry ID: https://osf.io/zm3j6 .

**Keywords:** Skill-related performance; Shooting; Team Sports; Sports engineering; Measurement error; Validity; Reliability; Quality control.

## Introduction

Soccer is well-known as one of the most practiced and watched sports around the world, estimated at 5 billion in the last FIFA World Cup Qatar 2022™ edition [1]. A main action in soccer is the kicking. Kicking is defined as a form of striking in which the foot is used to deliver force against an object [2]. In the case of soccer, the ball is the desired object for kicking (e.g., for passing or shooting). Despite the evident importance of ball kicking to soccer performance, the quantity and quality of investigations are not proportional to its relevance to the game.

The lack of sufficient evidence to assist practice is evidenced, for example, by the limited number of investigations available in the form of scientific articles assessing practical interventions and their effects on ball-kicking movement [3]. While adopting field paradigms is desired when measuring/testing kicking skills in soccer [4], the difficulty of capturing player movement kinematics under field conditions may justify in part the scarcity of literature (e.g., large time-frame from data collection to results report) [5–7]. In this context, the emergence of technologies that can overcome such limitations is therefore necessary.

Wearables represent a range of devices that can be worn or attached to the body to record data and comprise, in general, two categories: independent running devices (primary) or devices that require offline transference to a primary wearable device [8]. Wearables have been extensively used to measure load demands (internal and/or external). At the same time, this can also be employed in additional sport-specific movements, such as evaluating technical aspects of game-play [9], including but not restricted to ball kicking. One advantage of wearable devices, which provide kinematic outputs, as compared to traditional video-based tracking techniques, refers to their generally reduced costs and time effectiveness [6]. From an initial search of the existing reviews on wearables in the context of sport, only preliminary evidence is found concerning its validity to soccer kicking analysis (Table 1). Most importantly, none of the previous reviews have solely examined the application of wearables to investigate ball kicking in soccer. Given the importance of the subject, a dedicated analysis is justified.

Defining some further concepts in advance is necessary when proposing a protocol for a systematic review of the measurement properties (e.g., validity and reliability) of wearables used to measure ball kicking. The first one refers to "validity", which can be assumed as whether one given instrument measures the characteristic it was designed to quantify. Reliability represents more the variation of the tool, protocol and/or human system [10]. Measurement error is the difference between a measured value and the actual (known) value [11]. Finally, a systematic review aims to group all the available scientific evidence, using pre-established eligibility criteria and explicit and systematic methods, to offer a more comprehensive, detailed, and less biased view of a particular research question [12].

**Table 1.** Initial search for review studies potentially addressing wearable technology and soccer kicking assessment.

| Reference | Guidelines | Date of searches/inclusion | Databases | Results related to measurement properties of wearable technologies to measure soccer kicking |
|---|---|---|---|---|
| Adesida et al. [13] | -- | from inception up until 31st October 2018 | Scopus, Medline, Embase, Cochrane Library, IEEE Xplore, Web of Science (Core Collection) and Engineering Village | Good concurrent validity between MVN Link IMS and Vicon, despite the higher error in segments showing fastest movements (1 study); Approximately 99% accuracy of a wearable sensor to detect kicks (1 conference proceeding); Descriptive data of application of wearables in kick investigations (2 studies) |
| Camomilla et al. [14] | PICOS framework | Until 12 April 2017 | Web of Science, Scopus, Pubmed, and Sport Discus | Mention of devices assessing the accuracy of wearable sensors to detect kicks (2 studies); Descriptive data of application of wearables in kick investigations (1 study) |
| Cardinale & Varley [15] | -- | Search on July 2016 | PubMed | None information |
| Chambers et al. [9] | -- | Published between 2008 and 2014 | Academic Search Complete, CINAHL, PsycINFO, PubMed, SPORTDiscus and Web of Science. | None information |

| | | | | |
|---|---|---|---|---|
| Crang et al. [16] | PRISMA statement | From earliest record to March 2020 | SPORTDiscus, CINAHL and Medline | None information |
| De Fazio et al. [17] | -- | -- | -- | None information |
| Fong & Chan [18] | None mentioned | From 1966 to July 2010 | Medline, ISI Web of Knowledge (Science Citation Index Expanded), Social Sciences Citation Index, Arts & Humanities Citation Index, SportDiscus and IEEE Xplore | None information |
| Lutz et al. [19] | -- | -- | -- | None information |
| Poitras et al. [20] | PRISMA | After 2005 to July 2018 | PubMed, CinAHL, Ergonomic abstract, Compendex, and EMBASE | Mention of validity results to Xsens MVN BIOMECH (Xsens technologies B.V., Enschede, the Netherlands) (1 study) |
| Rana & Mittal [7] | -- | -- | -- | Mention of devices assessing the accuracy of wearable sensors to detect kicks (2 conference proceedings); Descriptive data of application of wearables in kick investigations (3 conference proceedings) |

Therefore, the present study aims to provide a protocol for a systematic review focused on understanding the measurement properties (validity, reliability and/or measurement error aspects) of wearable technology systems used explicitly to measure ball-kicking features in soccer. The future review using the protocol described here will assist in answering the following question: Are the available wearables accurate enough to quantify soccer kick mechanics, especially under field conditions?

## Methods

## Registration

The review protocol was pre-registered in the Open Science Framework (OSF) Registries/Generalized Systematic Review Registration (Registry ID: https://osf.io/zm3j6). The current protocol for this systematic review, as presented in full below, was also formulated according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement 2020 version [21].

## Electronic databases and search strategy

Searches will be performed by two authors (LV and FM) in the following electronic databases: (1) PubMed (National Library of Medicine, USA), (2) Physical Therapy and Sports Medicine (Gale OneFile, USA), (3) Web of Science (WoS; Clarivate™, UK), (4) ProQuest (ProQuest LLC, USA), (5) IEEE Xplore (Institute of Electrical and Electronics Engineers, USA), (6) EBSCOHost (EBSCO Information Services LLC, USA), and (7) Scopus (Elsevier B.V., The Netherlands). No restrictions will be imposed concerning the date of publication, that is, articles will be considered for inclusion when published, even online ahead of print, from inception up to the date of searches. The searches will be updated if necessary. The Zotero software (v6.0.30; Corporation for Digital Scholarship, Roy Rosenzweig Center for History and New Media at George Mason University) will be used to manage reference entries from the initial search to the final inclusion steps. According to a specific PICO (Population, Intervention, Comparison, Outcome) framework [22], studies will be screened looking for those which (P) participated able-bodied soccer players, (I) evaluated with at least one wearable device/system, (C) that was compared against criterion measures (i.e., tested validity), between testing sessions (i.e., tested reliability) and/or real known values (i.e., tested measurement error) and (O) reported data for ball kicking action. Thus, search terms attempted to respect such defined PICO framework and are presented in Table 2 using a Boolean search strategy, also considering those key terms used previously in existing systematic reviews [3,16,20].

**Table 2.** Search strategy formulated for each specific database considered

for the present study review/protocol.

**PubMed**

((((soccer[Text Word]) OR football*[Text Word]) OR association football[Text Word]) OR 11-a-side[Text Word]) AND ((((((((((wearable*[Text Word]) OR inertial measurement unit[Text Word]) OR IMU[Text Word]) OR acceleromet*[Text Word]) OR microtechnology[Text Word]) OR micro-electrical mechanical system[Text Word]) OR MEMS[Text Word]) OR global positioning system[Text Word]) OR global navigation satellite system[Text Word]) OR local positioning system[Text Word]) OR GPS[Text Word]) OR GNSS[Text Word]) OR LPS[Text Word]) AND (((((validity[Text Word]) OR reliability[Text Word]) OR measurement error[Text Word]) OR accuracy[Text Word]) OR precision[Text Word]) AND (((((kick*[Text Word]) OR shoot*[Text Word]) OR pass*[Text Word]) OR skill[Text Word]) OR technical[Text Word])

**Web of Science**

TS=(((((soccer) OR football*) OR association football) OR 11-a-side) AND ((((((((((wearable*) OR inertial measurement unit) OR IMU) OR acceleromet*) OR microtechnology) OR micro-electrical mechanical system) OR MEMS) OR global positioning system) OR global navigation satellite system) OR local positioning system) OR GPS) OR GNSS) OR LPS) AND ((((((validity) OR reliability) OR measurement error) OR accuracy) OR precision) AND ((((kick*) OR shoot*) OR pass*) OR skill) OR technical))

**EBSCOHost**

( soccer OR football OR association football OR 11-a-side ) AND ( wearable* OR inertial measurement unit OR IMU OR acceleromet* OR microtechnology OR micro-electrical mechanical system OR MEMS OR global positioning system OR global navigation satellite system OR local positioning system OR GPS OR GNSS OR LPS ) and ( validity OR reliability OR measurement error OR accuracy OR precision ) AND ( kick* OR shoot* OR pass* OR skill OR technical )

**SCOPUS**

( TITLE-ABS-KEY ( soccer OR football OR "association football" OR 11-a-side ) AND TITLE-ABS-KEY ( wearable* OR "inertial measurement unit" OR imu OR acceleromet* OR microtechnology OR "micro-electrical mechanical system" OR mems

OR "global positioning system" OR "global navigation satellite system" OR "local positioning system" OR gps OR gnss OR lps ) AND TITLE-ABS-KEY ( validity OR reliability OR "measurement error" OR accuracy OR precision ) AND TITLE-ABS-KEY ( kick* OR shoot* OR pass* OR skill OR technical ) )

**ProQuest**

noft(soccer OR football OR association football OR 11-a-side) AND noft(wearable* OR inertial measurement unit OR IMU OR acceleromet* OR microtechnology OR micro-electrical mechanical system OR MEMS OR global positioning system OR global navigation satellite system OR local positioning system OR GPS OR GNSS OR LPS) AND noft(validity OR reliability OR measurement error OR accuracy OR precision) AND noft(kick* OR shoot* OR pass* OR skill OR technical)

**Physical Therapy and Sports Medicine/Gale OneFile**

Entire Document: soccer OR football OR association football OR 11-a-side AND Entire Document: wearable* OR inertial measurement unit OR IMU OR acceleromet* OR microtechnology OR micro-electrical mechanical system OR MEMS OR global positioning system OR global navigation satellite system OR local positioning system OR GPS OR GNSS OR LPS AND Entire Document: validity OR reliability OR measurement error OR accuracy OR precision AND Entire Document: kick* OR shoot* OR pass* OR skill OR technical

**IEEE Xplore**

("All Metadata":soccer OR "All Metadata":football OR "All Metadata":association football OR "All Metadata":11-a-side) AND ("All Metadata":wearable* OR "All Metadata":inertial measurement unit OR "All Metadata":IMU OR "All Metadata":acceleromet* OR "All Metadata":microtechnology OR "All Metadata":micro-electrical mechanical system OR "All Metadata":MEMS OR "All Metadata":global positioning system OR "All Metadata":global navigation satellite system OR "All Metadata":local positioning system OR "All Metadata":GPS OR "All Metadata":GNSS OR "All Metadata":LPS) AND ("All Metadata":validity OR "All Metadata":reliability OR "All Metadata":measurement error OR "All Metadata":accuracy OR "All Metadata":precision) AND ("All Metadata":kick* OR "All Metadata":shoot* OR "All Metadata":pass* OR "All Metadata":skill OR "All Metadata":technical)

## Inclusion and exclusion criteria

This review will include studies presented in the form of (a) original research articles (independent of its design), (b) written in the English language, (c) published in scientific journals with peer-review policy, (d) with full-text available for download, and (e) abstract available for screening in the respective database. Suppose there is no option to obtain full-text in its original database, in that case, additional searches can be conducted in Google Scholar (Google LLC), allowing for potential inclusion of studies from ResearchGate™ (ResearchGate GmbH). As an additional inclusion criterion, (f) studies will be only considered for inclusion in the present systematic review project when they have respected the fundamental ethical principles consistent with the Declaration of Helsinki by including in the full-text such information that an institutional research ethics committee approved the investigation with human subjects [23] or otherwise whether there is an explicit statement indicating that evaluations were done as a part of traditional athletes routine measurements (e.g., occupationally based work or given a requirement of employees) which may allow the absence of prior approval by an appropriate body [24].

Those studies (a) examining only the application/feasibility of wearable(s) device(s), (b) observations/experiments only addressing football codes movements other than ball kicking, (c) reported as conference proceedings, books, thesis, dissertations, literature reviews, opinion pieces, case studies, (d) where a ball was not kicked, (e) with outcomes only concerning motion/flight of the ball, (f) without mention of the location(s) where the wearable system/device was attached to the body of evaluated subjects will be excluded. A third researcher with long-term experience in the area (FMC) will resolve cases if no consensus is reached by the three authors in charge of searches/selection of studies.

## Methodological quality and risk of bias assessments

The methodological quality of the included studies will be determined using the COSMIN checklist, specifically the forms H (for criterion validity), B (for reliability), and/or C (for measurement error) [25,26] where appropriate (e.g., if an included study evaluated criterion validity then the form H will be used for the case). In addition, the Risk of bias (RoB) of results or inferences will be computed for each study included separately through the Risk of Bias Assessment Tool for Nonrandomized Studies (RoBANS; Kim et al., 2013). Each item will be assessed as having low, high, or unclear risk concerning criteria of selection of participants, confounding variables, measurement of exposure, blinding of outcome assessments, incomplete outcome data, and selective outcome reporting. Review Manager software (RevMan, version 5.3; The Cochrane Collaboration, Denmark) [28] will be employed to construct the RoB graphs for individual studies as well as all results of all studies pooled. Two authors (WO and KV) will perform the processes independently.

## Data extraction and evidence synthesis

Data extraction will be made (by LV and KV) using a specific spreadsheet, and parameters considered to be included will be selected after piloting, with approximately 10 studies among those included. In general, we expected to extract the following data from included studies: correlation coefficients, intraclass correlation coefficient, root mean square error, respectively, for studies reporting validity, reliability and/or measurement error [20] in addition to study characteristics including as for example device employed, time used, kick protocol, measured variable and concluding remarks [29]. Following on, the "best evidence synthesis method" will be applied to classify the level of evidence across included studies [30]; consistency has been defined when ≥ 75% of studies reported results in the same direction, while inconsistency when < 75% of studies reported results in the same direction [3,31,32]. Thus, the following thresholds will be used:

- Strong evidence: consistent findings obtained from multiple high-quality studies;
- Moderate evidence: consistent findings obtained from multiple low-quality and/ or one high-quality study;
- Limited evidence: findings obtained from only one low-quality study;
- Conflicting evidence: inconsistent findings obtained from multiple studies;
- No evidence: no study found.

For all steps where two evaluators are requested above (i.e., literature search/selection, methodological quality/bias, and data extraction), inter-evaluator agreement will be assessed using Cohen's kappa coefficient and then the average value across measures will be reported in the final systematic review manuscript.

## Results

This systematic review project is ongoing. At the moment of submission, database searches were completed (i.e., identification step), and the present authors are beginning the screening step. If there is a sufficient number of studies (i.e., three or more on a given dependent variable) and no substantial variations are detected concerning methods used across studies, results can also be presented through a meta-analysis (quantitative synthesis). Sub-group analysis, if pertinent, will consider, for example, gender, age, and playing level. Finally, independent of whether the final manuscript will qualify for quantitative synthesis or not, qualitative synthesis will be performed using the best evidence synthesis method. In addition, a table in attachments containing main study characteristics will be included (e.g., aim, results, and findings). Results are predicted to be complete by May 2024, and final systematic review manuscript submission by August 2024.

## Discussion

In this article, we set out to provide a detailed protocol for a future systematic review of the measurement properties of wearables adopted to investigate ball kicking. Ensuring data quality through the integration of new technological devices is crucial for minimizing bias in research publications and the decisions derived from using such instruments in daily practice. Therefore, scientific publishing must prioritize accuracy, as measured in concurrent-validity studies, and reliability [33].

Recognizing the increasing demand for ecologically focused soccer drills [34] and acknowledging the opportunities presented by new technologies for incorporating measurement systems into training, the utilization of wearables in ecological scenarios emerges as a high-value proposition. Indeed, this approach offers a viable solution to overcome the constraints associated with gold-standard motion-based devices, which are typically limited to specific locations, predominantly within laboratories.

With the progress in microsensors, we anticipate observing satisfactory levels of concurrent validity in wearable inertial measurement units, as supported by prior original research [35,36]. The majority of kinematic measures exhibiting acceptable concurrent validity and reliability are expected to be associated with ball release velocity [36], representing an outcome of the kicking process. Meanwhile, other outcomes will be linked to the inherent quality of movement, seeking to characterize the kinematic profile of players [35,37] by measuring linear, angular, or joint velocities.

The outcomes of this systematic review will offer researchers and practitioners a means to comprehensively summarize the evidence regarding the quality of data extracted from wearable devices for measuring kicking performance. This will enable the identification of the most accurate and reliable devices, pinpoint gaps in current research, and identify new research directions and developments that need attention in the coming years.

## Conclusions

To our knowledge, this will be the first systematic review of scientific literature to attempt to collate knowledge derived from peer-reviewed articles that covered the measurement properties related to the use of wearable devices to capture ball-kicking kinematics. A systematic review of scientific studies addressing this issue will potentially help, for example, to a) highlight which instruments are effective in day-to-day testing/monitoring of kicking performance, b) to understand the potential sources of variability (e.g., specific environmental properties), and c) to clarify the operator attitudes (e.g., configurations) that could be adopted as a way of capturing adequately the event of interest - ball kicking – which itself is not a trivial task. Thus, it is possible to conclude that the protocol proposed here will benefit practitioners and football scientists, together with the final results from the systematic review with the best evidence synthesis.

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## Conflicts of Interest

None declared.

## Abbreviations

COSMIN: COnsensus-based Standards for the selection of health Measurement Instruments
EBSCO: Elton B. Stephens COmpany
FIFA: Fédération Internationale de Football Association
GNSS: Global navigation satellite system
GPS: Global positioning system
IEEE: Institute of Electrical and Electronics Engineers
IMU: Inertial measurement unit
LPS: Local positioning system
MEMS: Micro-electrical mechanical system
noft: Anywhere except full text
OSF: Open Science Framework
PICO: Population, Intervention, Comparison, Outcome
PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses
RoB: Risk of bias
RoBANS: Risk of Bias Assessment Tool for Nonrandomized Studies
TS: Topic
WoS: Web of Science

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