Work in progress: reviewing measurement properties of wearables applied to compute ball kicking features

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Abstract*– Data collection and analysis of the soccer kicking skill is one of the biggest challenges encountered in biomechanics applied to soccer. Reasons includes, as for example, the speed demands of this particular task. In general, kicking involves a rapid change from low speed (approximately in the final of support phase) to high speed (at foot-ball impact) in a very short time interval. Thus, kinematic systems used to capture kick motion should present high levels of accuracy. Given such requirement, automatic 3-dimensional optical methods (e.g. based on segmentation principles) have been commonly applied to investigate ball kicking. However, its use is traditionally limited to only laboratory-based scenarios. Even if there is the possibility to adopt more flexible systems (e.g. semi-automatic video-based tracking) in a naturally occurring environment, issues like occlusion still persists in some cases. Nonetheless, regardless of which of the two models described above is used, intensive post-collection data processing work may occur. Thus the provision of advanced systems that may overcome previous limitations are required to assist improve ecological validity and practical utility of soccer kicking data. In this context, wearable devices emerges as one of the potentially candidates to attempt fill this important gap in research and practice. Here we provide further rationale and preliminary findings from a research project aiming at provide a review on the measurement properties of wearable devices applied to compute ball kicking features. The study is proposed considering that no previous reviews on the validity of wearables collated data solely about ball kicking. An initial search was performed in the MEDLINE database. Six studies were retained after applying inclusion and exclusion criteria. Methodological quality was assessed using a modified version of the STROBE tool. Best evidence synthesis method was then applied to classify the level of evidence obtained across studies (ranging from no evidence to strong evidence level). In short, we have found moderate evidence supporting validity and reliability of some wearable devices to determine ball kicking indices. While wearables generally presented strong evidence confirm its validity and reliability (i.e. when pooling all devices/methods), future conclusion of the project will allow to confirm if the results presented here can be generalized, in particular concerning individual technologies.

Keywords-- Technology, Ecological validity, Measurement error, Biomechanics, Sports engineering.

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I. Introduction

Ball kicking is constantly performed across a soccer match. Examples includes passing the ball between teammate players and shooting the ball aiming at scoring a goal. Both indicators mentioned above are associated to final result of matches and subsequent classification in competition [1] – [3]. Given the importance of ball kicking to success in soccer, measuring the kicker features (e.g. lower limb kinematics) are therefore necessary to help practitioners (i) know the demands associated to this particular action; (ii) identify potentially individual weaknesses requiring adjustment through training and (iii) quantify the degree and effectiveness of interactions amongst teammates (e.g. passing networks) [4].

Measuring kicking parameters (e.g. testing) in particular the player movement kinematics, under field conditions - i.e. in the naturally occurring environment - remained challenging for several decades [5], [6]. Using video-based systems in such circumstances generally requires a proficient team equipped with the expertise to collect, process images and analyze data, and occasionally this is also linked with intensive laboratory-based work. This is even more complicated when adding contesting players to the task in order to increase ecological validity, or in an official match condition; both may generate severe occlusion effects. Artificial-intelligence assisted motion analysis based on the markerless principle represent a significant advancement to some previous limitations. However, it still requires image processing, and thus previous filming is necessary. Consequently, there is a possibility that reports will potentially not always come out on adequate time to the hands of coaching staff; this is suggested to range between 24 to no more than 36 hours [7].

In the context when only limited possibilities exist to use video-based kinematics systems, wearables (e.g. inertial measurement units – IMU) appears as a candidate for helping provide real-time and accurate data. One additional key advantage of wearable devices is that some of them can be used in large areas; traditional videogrammetry methods have restricted capture volumes. Also, financial requirements generally declines when adopting wearable systems [8]. Taken together, its use is justified as in the case of soccer kicking skill. However, to the extent of our knowledge there are no previous dedicated reviews addressing solely the validity aspects of such technology type to measure ball-kicking indices. Subtle changes from low to very high speed signals are generally found in the action and represents a challenge to researches and practitioners when processing and interpreting data from kicking. Thus, before implementing any new technology in soccer practice and play it is pertinent to verify the quality of the capture system (e.g. validity, reliability and/or measurement error aspects).

Based on the above rationale, the main objective of the present study was to provide an initial synthesis of current literature on the measurement properties of wearable devices applied to compute ball kicking features.

II. METHODS

This study represents an ongoing project in which the full protocol was previously registered in the Open Science Framework – OSF domain (registry ZM3J6; Date registered: January 13, 2024).

An initial electronic database search was performed on 01/02/2024 through the MEDLINE database (National Library of Medicine, United States government) using a Boolean strategy considering the following key terms: [soccer OR football] AND [wearable* OR inertial measurement unit OR IMU OR microtechnology] AND [validity OR reliability OR precision] AND [kick* OR shoot* OR pass*]. The Zotero v6.0.30 software was used to store and screening of results - title entries - identified from the search above mentioned.

We have considered for inclusion original studies published in peer-reviewed journals with full-text available in English. Studies were excluded if addressed only ball flight data, examining feasibility of application of wearables and without information on the location where the device was attached in the participants. After selection, data extraction was performed to collate characteristics from the included studies to allow for subsequent methodological quality assessment using a modified version of the STROBE assessment criteria. Methodological quality was then assessed using 10 questions (2-point scale for each: 1 = completed and 2 = non-completed), as proposed elsewhere in [9]. This specific scale allowed to classify studies as having low risk of bias (≥ 7 questions equals to 1) or high risk of bias (> 3 questions equals to 2).

To summarize results, best evidence synthesis method was applied to classify the level of evidence obtained across findings from studies. For such purpose, the following thresholds were adopted: strong evidence (consistent findings observed among multiple high-quality studies), moderate evidence (consistent findings observed among multiple low-quality and/or one high-quality study), limited evidence (findings observed from only one low-quality study), conflicting evidence (inconsistent findings observed among multiple studies) or no evidence (none found). Consistency is represented by ≥ 75% of studies reporting results on the same direction.

III. RESULTS

Eight studies were found to be considered for potential inclusion from the initial searches (Fig. 1). After reading its full-text, six articles [10] – [15] were included and appraised. Reasons for excluding two studies included one paper showing data of kicking only aggregated with other actions and another paper only on rugby union players. Most studies showed low risk of bias [10] – [14]. There was only one exception [15].

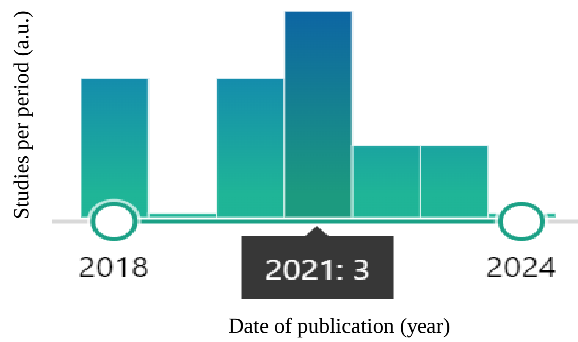

Fig. 1 Number of initial title entries found per year of publication.

Three studies investigated validity aspects of wearables in determining ball kicking [10], [12], [13]. Reference [10] contrasted results of an IMU system (Xsens Technologies B.V., Enschede, the Netherlands) against an optical system (T-40 series, Vicon Nexus v2, Oxford, UK) when collecting kicking data of amateur adult players and reported good concurrent validity despite error showing a trend toward being speed-dependent in some cases, i.e. foot segment with greater error than other body parts. Similarly, [13] tested another IMU system (PlayerMaker™, Tel Aviv, Israel) also against video-based system (Quintic Consultancy Ltd, Sutton Coldfield, UK) in professional soccer players and results indicated very large correlations between systems for ball release velocity. In [12], the cross-validity of accelerometer (GENEActiv monitor; Activinsights, Cambridge) derived passing measures was assessed in healthy children and the tool demonstrated sensitiveness to distinguish between this activity and others.

Two studies investigated reliability aspects [11], [13]. Reference [11] analysed the inter-day reliability of kicking measures derived from an IMU system (VICON IMeasureU Blue Trident dual-g sensors; IMeasureU, Auckland, New Zealand) and revealed better results from the non-dominant as compared to dominant limb in reference to impact load; step count showed also fair reliability while cumulative bone stimulus had excellent level. In addition to establishing validity as aforementioned, [10] also presented additional within-session analysis, indicating moderate to high reliability for ball release velocity and this seems to be inversely dependent on the degree of kick intensity (i.e. high ball release velocity linked to low reliability).

Measurement error (accuracy) aspects of wearables used to classify kicking action occurrences was determined in two studies [14], [15]. In a sample of both youth and adult players ranging from novice/amateur to semi-professional, [14] tested three neural networks to identify shot and pass events from IMU signals (unspecified brand) and the convolutional neural network (CNN) showed superior performance (92.8%). Reference [15] used a public dataset of accelerometer data (unspecified brand) and also compared three classification methods, indicating that "IoT-WAP" (Internet of Things-assisted wearable device for activity prediction) model reported the higher accuracy (94.55% and 92.33% respectively for kicking and passing).

Finally, based on the best evidence synthesis analysis, it is possible to state that there is strong evidence that wearables – pooled studies – shows good concurrent validity in relation to video-based methods. The same is valid for reliability of wearable devices. In the case of accuracy to classify kick events, the level of evidence supporting wearables is moderate. However, the summarization does not hold true at the level of specific devices/methods used, owing that they varied across studies. As a consequence, the level of evidence is classified as moderate for each device/method reported in the included studies, excepting the IoT-WAP for which the level of evidence is limited.

IV. CONCLUDING REMARKS

From the preliminary literature search presented here, it is possible to suggest that there are moderate evidence supporting validity, reliability and measurement error of some wearable systems. When looking in general – regardless of devices/method specificities – wearables presents strong evidence supporting its validity and reliability according to reported in research articles available in the MEDLINE database. Future conclusion of the present project (i.e. searching through further electronic databases) will potentially help confirm whether generalizability of the findings presented here can be extended to a wider literature.

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