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Usage of Motion Capture in Football for Creating Motion Template: A Systematic Literature Review

Amir Irfan Mazian[1], Wan Mohd Rizhan Wan Idris[1,*], Normala Rahim[1], Muhammad Danial Zakaria[1], Mohd Sufian Mat Deris[1], Ahmad Rafi Mohamed Eshaq[2], Fadzli Syed Abdullah[3], Zulfachmi[4]

[1] Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, 22200 Besut, Terengganu, Malaysia
[2] Faculty of Creative Multimedia, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia
[3] Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia
[4] Informatic Engineering, Sekolah Tinggi Teknologi Indonesia Tanjung Pinang, Jalan Pompa Air No. 28, K.M 2,5 – Tanjungpinang, Kepulauan Riau, Indonesia

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ABSTRACT

The utilization of motion capture technology in sports that focuses within the football has received significant interest due to its potential to improve performance of the player, facilitate tactical analysis, and mitigate the risk of injuries. However, it appears that there is lack of knowledge on motion template creation and usage based on current research. The identification of this research gap not only emphasizes an area that has not been explored but also indicates an interesting area for future research. Hence, this systematic literature review focuses on the critical issue of using motion capture techniques to create comprehensive motion templates in the context of football. This study offers researchers, coaches, and football enthusiasts an extensive understanding of the potential benefits of motion template using motion capture technology in the context of football.

1. Introduction

Motion capture, often known as MoCap, refers to the computerized tracking and recording of motions performed by objects or living beings within a certain environment [1-3]. MoCap technology has undergone significant development over the years, resulting in its widespread availability for various applications. MoCap makes it possible to digitally capture and record body, hand, and facial movements that are based on performances by real people and others in high-fidelity both online and offline. This opens up a wide range of possibilities for its implementation, including 3D character animation, entertainment [4], the video game industry [5], martial arts [6], and more [7]. In addition, there has been limited utilization in industrial sectors such as robotic [8], automotive [9] and construction [10].

* *Corresponding author.*
E-mail address: wmrizhan@unisza.edu.my

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The integration of MoCap technology into the sports domain has brought about a significant transformation, allowing for a more comprehensive and detailed data analysis which can be used to inform decision-making, refine training programs, and prevent injuries. By utilizing cutting-edge technology, sports teams can now capture and analyse a vast array of physical and biomechanical data, such as the speed of an athlete, their range of motion, and even their heart rate during a game.

Sport provides many benefits to our health, improve our body fitness and affect people’s welfare [11]. In the 21st century, football, which is often referred to as soccer, has become known as one of the most popular sports played all over the world. At an amateur or recreational level, more than 300 million people from 203 different countries play it [12]. The dynamic and multifaceted nature of the sport demands a profound understanding of player motion, from sprinting and dribbling to tackling and shooting, which involves an intricate interplay of biomechanical variables.

In recent years, the use of MoCap technology in football has become more prevalent. The data from MoCap provides coaches and trainers with a more complete understanding of their athletes' performance, allowing them to fine-tune training programs and make informed decisions about player selection and game strategies.

Moreover, MoCap technology can be used to assess injury risk, enabling teams to take proactive measures to prevent injuries and ensure their athletes are performing at their best. For example, the technology can identify movements that put athletes at risk for injury, and trainers can adjust their training programs to mitigate those risks. The integration of MoCap technology represents a significant step forward for the sports industry, with the potential to revolutionize how we approach player performance and injury prevention [13].

The purpose of this systematic literature review is to provide an in-depth analysis of the most recent advancements of MoCap to create motion template for football. By synthesizing relevant studies, findings, and trends, this review aims to provide a comprehensive overview of the current state of MoCap technology in football.

2. Literature Review

In sports science and study on physical performance, motion capture technology has become very popular over the past few years. This comprehensive analysis examines the recent breakthroughs in motion capture technology and its many uses across several sectors. The previously mentioned categories involve all aspects of athletic performance, including coordination among soccer players, tracking movement in football, dynamics of diving boards, rehabilitation of injuries, protection of joints, and biomechanical evaluations during sports motions. In the subsequent parts, we will provide an extensive review of the results and implications obtained from these investigations.

Motion capture technology has played a significant part in clarifying the complexities of athlete performance within the field of sports science. The study conducted by Ren *et al.,* [14] investigated the impact of perceptual-cognitive activities on the coordination of football players, with a particular focus on the significant influence of cognitive elements in the field of sports. The hybrid methodology proposed by Aughey *et al.,* [15] utilises computer vision systems to track football movement, providing a viable method for evaluating football play on a broader scope. In their recent study, Yin *et al.,* [16] employed deep learning techniques to transform the field of football instruction. Their research focused on improving the accuracy of motion capture data, hence facilitating the development of more efficient coaching strategies.

The fields of injury rehabilitation and injury prevention have also been greatly impacted by motion capture technology. The study conducted by Madsen *et al.,* [17] examined the impact of anxiety levels on the recovery of runners, emphasising the significant contribution of psychological variables in the rehabilitation process. Demestre *et al.,* [18] have constructed a finite element model utilising motion capture data within the field of diving sports. This model aims to enhance comprehension of the interplay between divers and springboards, thereby explaining the mechanisms behind energy transfers and synchronisation, which are crucial components of diving board performance.

The study conducted by Grosklos *et al.,* [19] investigated the modified mechanics of the lower limbs in female individuals experiencing hip-related pain. The authors underscored the need of taking into account gender-specific movement patterns when developing strategies for injury prevention and rehabilitation. In their study, Zhang *et al.,* [20] conducted an investigation into the impact of elastic compression trousers on the safeguarding of joints during running. Their findings revealed the capacity of these garments to effectively stabilise joint movements, hence mitigating the likelihood of sustaining injuries.

In summary, motion capture technology serves as a fundamental component of contemporary sports science and study on physical performance. The results of this study collectively support the significant impact of motion capture technology in enhancing our understanding of sports science and enhancing athletic performance to unprecedented levels. With the ongoing advancement of technology, it is anticipated that motion capture will assume a more significant role in influencing the future of sports and research pertaining to physical performance.

3. Method

This systematic review complies to the guidelines set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [21] and the utilization of inclusion and exclusion rules as presented by Meline [22]. Three database search engines (IEEE, SpringerLink and Scopus) were used to identify eligible articles regarding motion capture usage in sport, specifically in football. This part includes a discussion of the four main sub-sections, namely identification, screening, eligibility, and data extraction [23].

2.1 Identification

The process of conducting a systematic literature review comprises three primary parts. The first step is keyword recognition that relates or similar terms based on thesaurus, dictionaries and previous study. Based on all the relevant terms on three databases, the search strings for IEEE, SpringerLink and Scopus were created (see Table 1).

Table 1
The search strings

IEEE	“Motion Capture” AND Sport
SpringLink	“Motion Capture” AND Sport
Scopus	TITLE-ABS-KEY ("motion capture" AND sport) AND PUBYEAR > 2017 AND PUBYEAR < 2023 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final"))

2.2 Screening

Through the previous phase of the systematic review process, 6215 papers were collected from databases. The database search yielded 296 articles from IEEE database, 4477 articles from SpringerLink database and 1442 articles from Scopus database. During this step, the articles underwent a filtering process based on many criteria. The primary and initial criteria is literature, namely in the form of a research article. The criteria for exclusion in the recent research encompass systematic reviews, book series, chapters, and conference proceedings. Additionally, only English-language publications were included in the review. It is essential to remember the scope of the publication for the past five years (2018-2022). A total of 4742 articles have been successfully removed from the entirety of the database, resulting in a remaining selection of 1422 articles. This reduction was achieved by eliminating 51 instances of duplication.

2.3 Eligibility

The third level, referred to as eligibility, contains a comprehensive collection of 1422 articles. To make sure the inclusion criteria were satisfied and the articles were appropriate for the present study's research goals, a careful review of all article titles and major textual material was done during this phase. Therefore, a grand total of 1406 publications were removed from the study due to of their title and abstract lacking significant relation to the research objective. There have been 16 publications made available for review in total (see Table 2).

Table 2
The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	Between 2018-2022	<2018
Literature type	Journal (only research articles)	Journal (book chapter, conference proceeding)

2.4 Data Extraction

The purpose of the research conducted by experts was to determine which themes and subtopics were significant. The stage of gathering data was the most important step in the process of developing the subject. As can be seen in Figure 1, the writers conducted an exhaustive search through a collection of 16 publications for sources of information or material that was related to the subjects of the present research. The publication's selected studies were analysed to record their general features and findings. This included information such as the article title, author, kind of motion capture used, target field of study, technique employed, assessment method, equipment and software utilized, as well as the number of individuals involved. Brainstorming processes begin between the writer and co-author to generate themes based on the evidence within the framework of this study.

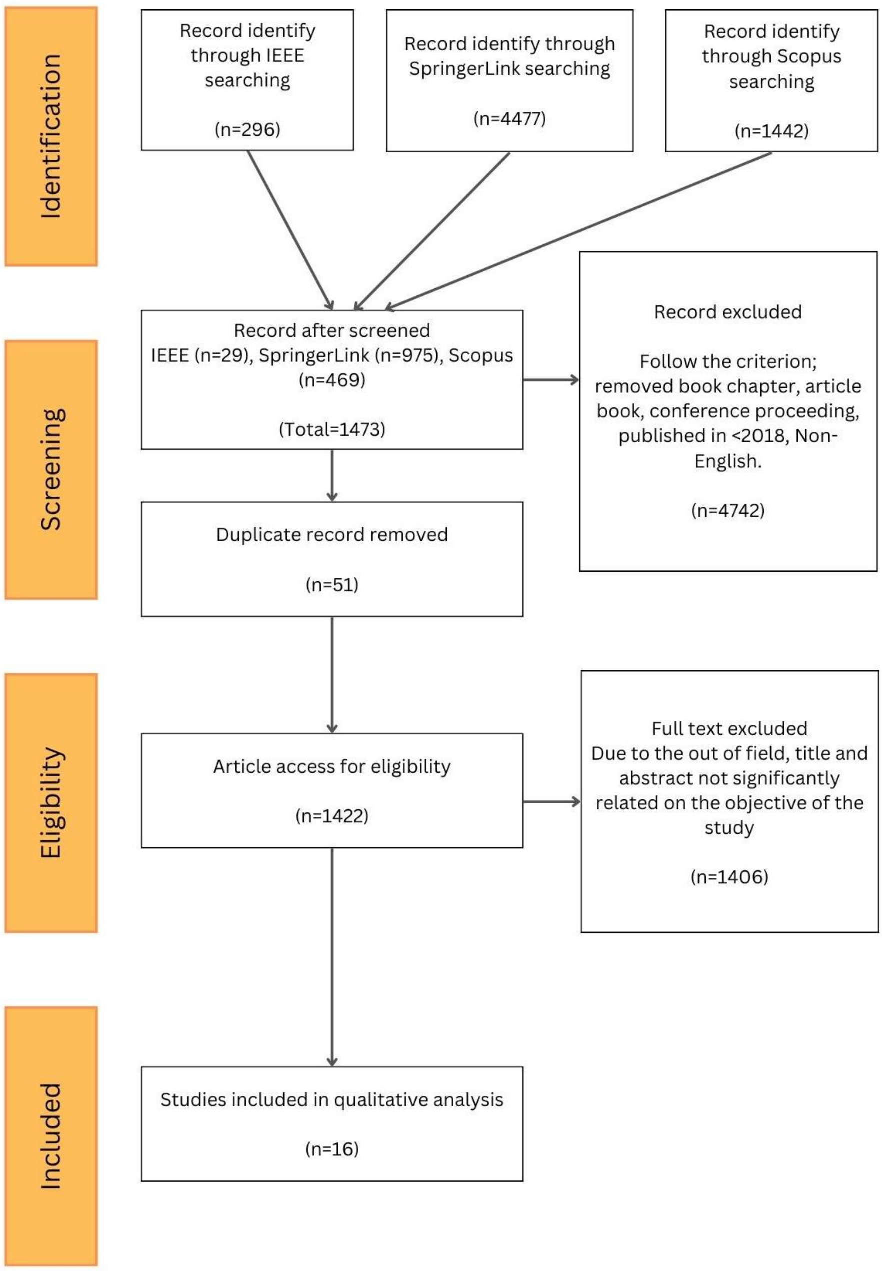

Fig. 1. Flow diagram of the proposed searching study

3. Result

All articles were categorized based on three main themes, which are marker-based MoCap technology, markerless MoCap technology and target area in football using MoCap technologies. The findings of the research were analysed and are shown in a concise format in table (see Table 3)

3.1 Marker-Based MoCap Technology

Marker-based MoCap technology typically consists of wearable equipment that is affixed with spherical or blob-shaped markers. Marker-based type is widely recognised as indispensable in various applications and industry sectors, including sports such as football and entertainment forms like dance [24]. Vicon, is one of the most motion capture device used in conducting data collection and experiment [14-16,25-31].

Although the fact that there is other type of MoCap solutions, marker-based motion capture continues to be widely regarded as the benchmark in the industry [7]. The reason for its exceptional tracking precision and frequency, along with its advanced level of development suitable for practical use, contributes to the production of high-quality result.

But there are some well-known flaws in the marker-based motion capture production process, which makes it far from perfect. The accuracy of raw optical motion capture data is frequently compromised by marker occlusions or mislabelling resulting from marker swaps during tracking. Additionally, this data may exhibit high-frequency noise or jitter, necessitating difficult manual post-processing.

Marker-based motion capture has been extensively utilised for collecting of participants' data in football, as evidenced by a significant proportion of review studies (87.5%) [12,14-16,25-34]. The statistical analysis reveals that the marker-based tracking method remains dependable due to its ability to accurately track motion with high precision.

3.2 Markerless MoCap Technology

Markerless MoCap (MMC) technology is a method that eliminates the need for markers to be placed on an individual's body. Instead, the system relies on visual hull reconstruction to collect and analyse the subject's movements [35].

The removal of physical limitations placed by body markers on movement has facilitated the advancement of MMC technology. This progress enables the realistic replication of human motion within various environments, employing a more organic approach. Notably, MMC technology utilises portable and cost-effective sensors, distinguishing it from marker-based multi-camera systems.

However, it is worth noting that in this analysis, only two studies have utilised this particular sort of markerless motion capture technology, accounting for 12.5% of the total studies reviewed [14,36]. The MMC technology exhibits considerable potential; a step forward in motion capture; however, more data processing and integration with other sensors, such as supplementary video cameras, are required to achieve a satisfactory level of accuracy [37].

3.3 Target Area in Football using MoCap

Based on the Table 3, there are only 11 studies collectively highlighting the widely usage of MoCap in medical area in football (68.75%) [12,25-33,36]. The medical area primarily concentrates on the assessment and management of injury risks, as example, in relation to the Anterior Cruciate Ligament (ACL) [25,32]. The physical state of the players was assessed through the implementation of numerous experiments, including the Drop Vertical Jump (DVJ) [25,36].

While the review in training area, it was found only 5 studies that resulting 31.25% from overall selected article, are demonstrate the application of MoCap technology. The evaluation of accuracy and acceleration [15,38] is important in the context of training area. The utilisation of a motion capture equipment enables the precise collection of data, which in turn permits experts to conduct analysis aimed at making improvements in this area.

However, none of article especially in training area mention or conducted study about motion template. The majority of studies employ MoCap technology to gather data and analyse it in order to obtain conclusive results pertaining to player performance, injury risk, and other related factors.

It can be concluded that the process is straight-forward, step-by-step and repetitive task, necessitating its execution each time in order to obtain the desired outcome.

Table 3
Summary of motion capture technology usage in football

Title	Author	Type of Motion Capture	Target Area	Technique	Evaluation	Device & Software	Number of Participant
Comparison of knee and hip kinematics during landing and cutting between elite male football and futsal players [12]	Daneshjoo A., Nobari H., Kalantari A., Amiri-Khorasani M., Abbasi H., Rodal M., Pérez-Gómez J., Ardigò L.P.	Marker	Medical	Mean and Standard Deviation of kinematic	Differences in landing and cutting manoeuvres between groups in hip flexion, knee flexion and knee valgus angle.	Raptor-H six-camera (Motion Analysis System, Cortex, Rohnert Park, CA, USA), and a three-dimensional motion analysis system (Raptor-H Digital Real Time System) at a sampling frequency of 120 Hz.	40
Effects of perceptual-cognitive tasks on inter-joint coordination of soccer players and ordinary college students [14]	Ren Y., Wang C., Lu A.	Marker	Training	Mean Absolute Relative Phase (MARP) & Deviation Phase (DP)	Effect of Perceptual-Cognitive Task	Vicon, Force platform	35
Comparison of a computer vision system against three-dimensional motion capture for tracking football movements in a stadium environment [15]	Aughey R.J., Ball K., Robertson S.J., Duthie G.M., Serpiello F.R., Evans N., Spencer B., Ellens S., Cust E., Haycraft J., Billingham J.	Marker	Training	Root Mean Square Deviation (RMSD)	Speed, Accuracy	Vicon, VisionKit	10
Motion capture and evaluation system of football special teaching in colleges and universities based on deep learning [16]	Yin X., Vignesh C.C., Vadivel T.	Marker	Training	Deep Learning Assisted Motion Capture System (DL-MCS)	Complexity, Performance, Latency, Efficiency	Multiple Vicon cameras	>1

Effects of a soccer-specific vertical jump on lower extremity landing kinematics [25]	Mancini S., Dickin D.C., Hankemeier D., Ashton C., Welch J., Wang H.	Marker	Medical	ANOVA	Kinematic differences between the drop vertical jump (DVJ) and the soccer-specific vertical jump (SSVJ) in female soccer athletes to better assess the sport-specific risk for ACL injury	8 Vicon Vantage and Vero Motion Capture cameras & Vicon Nexus software	8
The effects of visual cognitive tasks on landing stability and lower extremity injury risk in high-level soccer players [26]	Ren Y.,Wang C., Zhang L., Lu A.	Marker	Medical	Pair *t* test	Landing stability and lower limb injury	Vicon infrared high-speed motion capture system and three-dimensional force measuring platform	15
Effects of attentional focus cues on lower extremity kinematics during inside of the foot soccer trap among expert soccer players [27]	LoSarah L.L., Jagodinsky A.E., Torry M., Smith P.J.	Marker	Medical	Omnibus MANOVA & ANOVA	Differences between the internal and external cue conditions for the ankle and knee joints during the movement	16 camera Vicon MX optical motion capture system	10
Groin Injuries in Soccer: Investigating the Effect of Age on Adductor Muscle Forces [28]	Dupré T., Lysdal F.G., Funken J., Mortensen K.R.L., Müller R., Mayer J., Krahl H., Potthast W.	Marker	Medical	Kinematic analysis	Hip joint kinematics and effect of age on adductor muscle forces during submaximal soccer passing	- 16 F-40 Vicon infrared cameras - Vicon Nexus 2.3 software	60
A previous hamstring injury affects kicking mechanics in soccer players [29]	Navandar A., Veiga S., Torres G., Chorro D., Navarro E.	Marker	Medical	3-way ANOVA	Effects of gender and dominant limb on kicking legs with and without a hamstring injury	- 6 VICON camera & motion capture system	45

Mental stress reduces performance and changes musculoskeletal loading in football-related movements [30]	Auer S., Kubowitsch S., Süß F., Renkawitz T., Krutsch W., Dendorfer S.	Marker	Medical	t-test & NASA-TLX	Elite young football players' musculoskeletal reaction to stress-induced dynamic motions	- 12 VICON motion capture infrared camera.	12
A 2D qualitative movement assessment of a deceleration task detects football players with high knee joint loading [31]	Di Paolo S., Zaffagnini S., Tosarelli F., Aggio F., Bragonzoni L., Grassi A., Della Villa F.	Marker	Medical	2D scoring system	The deceleration task and to associate it with the knee joint loading	- Ten stereophotogrammetric camera. - Force platform. - 3 VICON Nexus high-speed cameras.	34
A 2D video-analysis scoring system of 90° change of direction technique identifies football players with high knee abduction moment [32]	Della Villa F., Di Paolo S., Santagati D., Della Croce E., Lopomo N.F., Grassi A., Zaffagnini S.	Marker	Medical	2D Video Analysis	Health Measurement on Anterior Cruciate Ligament (ACL) injury	10 stereophotogrammetric cameras, Force platform, Three high-speed cameras	34
Effects of maturation on knee biomechanics during cutting and landing in young female soccer players [33]	Westbrook A.E., Taylor J.B., Nguyen A.-D., Paterno M.V., Ford K.R.	Marker	Medical	Mixed-design ANOVA with the between group factor of maturation (PRE, PUB, POST) and withing group factor of task (DVJ, CUT)	Differences in knee control during a drop landing as well as an unanticipated cutting task	- 15 Cortex v7 camera motion analysis system	138
Kinematic Profile of Visually Impaired Football Players During Specific Sports Actions [34]	Finocchietti S., Gori M., Souza Oliveira A.	Marker	Training	Kinematic analysis	Visually impaired players present changes in their movement patterns in specific functional tasks compared with sighted amateur football players	- An Xsens MVN Link motion capture camera - Xsens MVN Studio software	14

Kinematic Differences Between the Dominant and Nondominant Legs During a Single-Leg Drop Vertical Jump in Female Soccer Players [36]	Nakahira Y., Taketomi S., Kawaguchi K., Mizutani Y., Hasegawa M., Ito C., Uchiyama E., Ikegami Y., Fujiwara S., Yamamoto K., Nakamura Y., Tanaka S., Ogata T.	Markerless	Medical	Pair *t* test	Kinematic differences between the actions of the dominant and nondominant legs during a single-leg drop vertical jump (DVJ) in female soccer players	Video motion capture with artificial intelligence	64
Validation of a LiDAR-based player tracking system during football-specific tasks [38]	Bampouras T.M., Thomas N.M.	Markerless	Training	LiDAR	Velocity and acceleration in football-specific tasks, Accuracy of tracking players, Calculation of relevant key performance indicators	Four-unit LiDAR system, 64-camera 3D motion analysis system	2

4. Conclusions

In summary, the majority of the studies that were selected for analysis mostly focus on the medical field, particularly in relation to the assessment of injury risks in football. There is lack of research that specifically examines the development of motion templates in football through the utilisation of MoCap technologies. MoCap is undergoing continuous advancements nowadays, presenting researchers with opportunity to explore this technology across several sports, not limited to football especially in producing motion templates. The potential of MoCap technology in the context of football is highly intriguing, and it elicits anticipation for further research endeavours in this area.

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