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Research Article

Assessment of Scientific Tools for Kinematic Analysis in Sports Performance

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Abstract:
Kinematic analysis is crucial in sports science and biomechanics for optimizing performance and helping in rehabilitation. This study compares fifteen kinematic analysis tools, namely Siliconcoach, Kinovea, Templo by Contemplas, Gaiton, Helix 3D By Rundna, Dartfish, Coach's Eye, Vicon, Motion Analysis Corporation, Noraxon Myoresearch, Qualisys, Pro-Trainer, Xsens, Simi Motion, And Shutter Precision. The comparison focuses on performance benchmarks, usability, accuracy, reliability, and cost-effectiveness. High-end systems like Vicon and Qualisys excel in precision and real-time data processing, ideal for research and professional use, while tools like Coach's Eye offer accessible yet less precise analysis suitable for general coaching. Usability varies, with Kinovea and Dartfish noted for their user-friendly interfaces, while advanced systems require more extensive training. Accuracy is critical, with top systems providing high precision through sophisticated technologies. Cost varies widely, from free tools like Kinovea to premium systems like Vicon. This study provides valuable insights for selecting the most appropriate scientific tools and methods.

Keywords: Biomechanics, Motion Capture Software, Performance Analysis, Sports Science, Video Analysis

1. INTRODUCTION

Importance of Kinematic Analysis in Sports Science

This study aims to compare various software tools used for kinematic analysis, evaluating their features, performance, usability, accuracy, and cost-effectiveness. Kinematic analysis is the scientific study of motion, which is an integral part of sports science. This field investigates the mechanics of body movements, particularly focusing on the movement patterns of athletes. Through kinematic analysis, sports scientists, coaches, and physiotherapists can gain deep insights into the efficiency, mechanics, and potential issues within an athlete's performance. The data obtained from kinematic analysis can be used to enhance training regimens, improve athletic performance, and prevent injuries. In sports science, the application of kinematic analysis spans across various domains. It is crucial to understand the biomechanics of movements in sports like running, swimming, and gymnastics (Matsuzaki et al., 2021).

By analyzing the kinematics of athletes, experts can identify suboptimal movement patterns and develop strategies to correct them. This is particularly important in sports where even minor improvements in technique can lead to significant performance gains (Selvakumar et al., 2021). The role of kinematic analysis extends beyond performance enhancement. Injury prevention is another critical area where kinematic analysis proves invaluable. By studying the movement patterns of athletes, it is possible to identify potential risks and develop preventive measures (Ajithkumar et al., 2022). For instance, an abnormal gait pattern might indicate a predisposition to lower limb injuries. Early detection of such issues allows for timely intervention, reducing the risk of severe injuries and extending the athletic careers of individuals (Lapresa et al., 2022).

Need for Reliable Software Tools

The precision and reliability of kinematic analysis are heavily dependent on the tools and software used. Traditional methods of motion analysis, such as manual video analysis, are time-consuming and prone to human error. The advent of sophisticated software tools has revolutionized kinematic analysis, providing accurate, detailed, and real-time data. These tools employ advanced algorithms and sensor technologies to capture and analyze motion (Kanko et al., 2020), offering a higher degree of precision than manual methods. Reliable software tools are essential for several reasons. Firstly, they ensure the accuracy of the data collected.

High-precision software can detect minute details in movement patterns that might be overlooked by the human eye. This level of accuracy is crucial for both performance enhancement and injury prevention. Secondly, reliable software tools offer consistency in data collection and analysis. Consistent data is essential for longitudinal studies where changes in an athlete's performance or biomechanics need to be tracked over time. In modern kinematic analysis software tools are equipped with features that facilitate comprehensive analysis. These features include multi-camera setups, real-time feedback, 3D motion capture, and integration with other measurement devices like force plates and EMG systems. Such capabilities enable a holistic approach to motion analysis, providing a complete picture of an athlete's performance (Pfister et al., 2016).

2. MATERIAL AND METHOD

The data were collected from various sources like scientific online database. Siliconcoach is a multipurpose tool known for its ease of use and detailed analysis capabilities. Key Features which exists as video capture, slow-motion playback, angle measurement, and comparison of multiple video clips. Kinovea is an open-source software popular among sports scientists for its user-friendly interface and powerful analysis features. Key Features which exists frame-by-frame video analysis, angle measurement, distance and speed tracking, and customizable overlays. Templo by Contemplas is A high-end tool designed for professional use in biomechanics and sports science. Key Features which exists multi-camera support, real-time feedback, comprehensive reporting, and integration with other measurement devices. Gaiton is a specialized software for gait analysis, commonly used in clinical and sports settings. Key Features which exists Detailed gait cycle analysis, spatiotemporal parameters, and customizable reports. Helix 3D by rundna is a focuses on 3D motion analysis, providing in-depth insights into running mechanics. Key features which exists 3D visualization, real-time feedback, and advanced data analytics. Dartfish is a Widely used in sports coaching for its robust video analysis and feedback tools. Key Features which exists Tagging and annotation, slow-motion analysis, and cloud-based sharing. Coach's Eye (Mobile) is A mobile app offering quick and accessible video analysis for coaches and athletes. Key Features which exists Video capture, slow-motion playback, and annotation tools. Vicon is A leading motion capture system used in both research and commercial applications. Key Features which exists High precision, real-time data capture, and extensive integration options.

Motion Analysis Corporation is a Provides comprehensive motion capture solutions with high accuracy. Key Features which exists Multi-camera setups, real-time analysis, and customizable software packages. Noraxon myoresearch is a Integrates kinematic analysis with EMG and other physiological measurements. Key Features which exists Synchronization of multiple data sources, detailed reporting, and user-friendly interface. Qualisys is a Offers high-end motion capture solutions with a focus on accuracy and reliability. Key Features which exists 3D motion capture, real-time feedback, and robust software support. Pro-Trainer is An advanced tool for biomechanical analysis in sports and clinical settings. Key Features which exists Detailed kinematic and kinetic analysis, customizable workflows, and comprehensive reporting (Longo et al., 2022). Xsens is Known for its wearable motion capture systems, providing flexibility and precision. Key Features: Inertial sensor technology, real-time response, and compatibility with other systems (Drapeaux & Carlson, 2020). SIMI Motion is A professional motion analysis tool in sports and biomechanics research. Key Features which exists Multi-camera support, real-time processing, and detailed reporting. Shutter Precision is A specialized high-speed video analysis tool commonly used in sports and engineering. Key Features which exists High frame rate capture, precise measurement tools, and customizable analysis options. Table 1 shows a comprehensive outline of subscription fee details along with data.

Table 1. Comprehensive outline of subscription fee details along with data

No	Software	Steps to Install	Subscription Fee Details	Fee in INR (Approx.)	Free/Trial Version
1	SiliconCoach	1. Download installer from SiliconCoach Website. 2. Run the installer. 3. Follow on-screen instructions to complete installation. 4. Launch and register with a valid license.	Personal License: $200/year. Professional License: $500/year. Institutional License: Custom pricing.	₹16,600/year ₹41,500/year	Free Trial: 30 days

2	Kinovea	1. Download from Kinovea Website. 2. Extract the downloaded file. 3. Run the setup file. 4. Follow the on-screen instructions.	Free and open-source. Free	Free Version: Unlimited
3	Templo By Contemplas	1. Contact CONTEMPLAS for the installer. 2. Download the provided installer. 3. Run the installer and follow the instructions. 4. Activate using the provided license key.	Basic Module: €1,500/year. Advanced Module: €3,000/year. Enterprise Module: Custom pricing. ₹1,32,000/year ₹2,64,000/year	Free Trial: 14 days
4	GaitON	1. Visit GaitON Website. 2. Download the installer. 3. Run the downloaded file. 4. Complete the setup wizard. 5. Register and activate using your account.	Personal License: $20/month. Professional License: $50/month. Enterprise License: Custom pricing. ₹1,660/month ₹4,150/month	Free Trial: 30 days
5	Helix 3D by RunDNA	1. Visit RunDNA Website. 2. Sign up and download the installer. 3. Run the installer. 4. Follow the on-screen instructions. 5. Activate with the provided license.	Basic Subscription: $49/month. Advanced Subscription: $99/month. Enterprise Subscription: Custom pricing. ₹4,070/month ₹8,220/month	Free Trial: 14 days
6	Dartfish	1. Go to the Dartfish Website. 2. Choose your plan and download the installer. 3. Run the installer. 4. Follow the setup instructions. 5. Sign in and activate your account.	Standard Plan: $5/month. Advanced Plan: $15/month. Professional Plan: $30/month. Enterprise Plan: Custom pricing. ₹415/month ₹1,245/month ₹2,490/month	Free Version: Limited features Free Trial: 15 days
7	Coach’s Eye (Mobile)	1. Visit your app store (Google Play or Apple App Store). 2. Search for "Coach’s Eye". 3. Download and install the app. 4. Open the app and follow the setup instructions. 5. Purchase the Pro version in-app if needed.	Basic Version: Free. Pro Version: $4.99/month or $29.99/year. Team Package: $120/year. Free ₹415/month ₹2,490/year ₹9,960/year	Free Version: Unlimited
8	Vicon	1. Contact Vicon for the software package. 2. Download the provided software. 3. Run the installer. 4. Follow the on-screen instructions. 5. Register and activate with provided credentials.	Nexus: Contact for pricing. Shogun: Contact for pricing. Blade: Contact for pricing. Support Package: Custom pricing. Contact for pricing	Free Trial: Contact for details
9	Motion Analysis Corporation	1. Contact Motion Analysis Corporation for the software. 2. Download the provided installer. 3. Run the installer. 4. Follow the setup instructions. 5. Activate with a valid license.	Software License: Starts at $10,000. Annual Maintenance: $2,500/year. Enterprise Solutions: Custom pricing. ₹8,30,000 ₹2,07,500/year	Free Trial: Contact for details

10	Noraxon myoResearch	1. Visit the Noraxon Website. 2. Request a demo and download the software. 3. Run the installer. 4. Follow the on-screen setup instructions. 5. Activate using the provided license.	Basic Package: Starts at $5,000. Advanced Package: Starts at $10,000. Enterprise Package: Custom pricing. ₹4,15,000 ₹8,30,000	Free Trial: 30 days
11	Qualisys	1. Contact Qualisys for the installer. 2. Download the provided software. 3. Run the installer. 4. Follow the setup instructions. 5. Register and activate with the provided license.	Basic License: Starts at $5,000/year. Professional License: Starts at $10,000/year. Enterprise License: Custom pricing. ₹4,15,000/year ₹8,30,000/year	Free Trial: Contact for details
12	Pro-Trainer	1. Visit Pro-Trainer Website. 2. Sign up and download the installer. 3. Run the downloaded file. 4. Follow the setup wizard. 5. Activate with your license key.	Individual License: $500/year. Team License: $1,500/year. Enterprise License: Custom pricing. ₹41,500/year ₹1,24,500/year	Free Trial: 14 days
13	Xsens	1. Visit the Xsens Website. 2. Choose your product and download the installer. 3. Run the installer. 4. Follow the setup instructions. 5. Register and activate with the provided license.	MVN Analyze: $500/month. MVN Studio: $1,000/month. Enterprise Solutions: Custom pricing. ₹41,500/month ₹83,000/month	Free Trial: Contact for details
14	SIMI Motion	1. Visit SIMI Website. 2. Request a demo and download the software. 3. Run the installer. 4. Follow the setup instructions. 5. Activate with the provided license key.	Basic Module: $2,000/year. Advanced Module: $4,000/year. Enterprise Module: Custom pricing. ₹1,66,000/year ₹3,32,000/year	Free Trial: 30 days
15	Shutter Precision	1. Visit Shutter Precision Website. 2. Sign up and download the installer. 3. Run the downloaded file. 4. Follow the setup wizard. 5. Activate with your license key.	Standard Package: $200/year. Professional Package: $500/year. Enterprise Package: Custom pricing. ₹16,600/year ₹41,500/year	Free Trial: 14 days

Administrator Privileges: Ensure you have administrative privileges on your computer, as many installations require it. System Requirements: Check the system requirements for each software to ensure compatibility with your hardware and OS version. Antivirus Software: Temporarily disable antivirus software if it interferes with installation (remember to enable it afterwards). Reboot if Necessary: Some installations may require a system reboot to complete the setup. Following these detailed steps, you can successfully install and start using each kinematic analysis software tool on a Windows operating system.

3. RESULT AND DISCUSSION

1.1 Result

The table description was given based on the availability of current sources, but features may change in the future. Each software tool provides unique features modified to different aspects of kinematic analysis. Table 2 shows a comparison between software features.

Table 2. Comparison between software feature.

Software	Video Capture	3D Analysis	Real-time Feedback	Integration	Customizable Reports
SiliconCoach	Yes	No	No	Yes	Yes
Kinovea	Yes	No	No	No	Yes
Templo by Contemplas	Yes	Yes	Yes	Yes	Yes
GaitON	Yes	No	No	Yes	Yes
Helix 3D by RunDNA	Yes	Yes	Yes	No	Yes
Dartfish	Yes	No	Yes	Yes	Yes
Coach's Eye	Yes	No	No	No	Yes
Vicon	Yes	Yes	Yes	Yes	Yes
Motion Analysis Corporation	Yes	Yes	Yes	Yes	Yes
Noraxon myoResearch	Yes	No	Yes	Yes	Yes
Qualisys	Yes	Yes	Yes	Yes	Yes
Pro-Trainer	Yes	Yes	Yes	Yes	Yes
Xsens	Yes	Yes	Yes	Yes	Yes
SIMI Motion	Yes	Yes	Yes	Yes	Yes
Shutter Precision	Yes	No	No	No	Yes

All the software analyzed in the comparison table shows video capture capabilities, making this feature universally available. However, the availability of 3d analysis is limited to advanced tools such as templo by contemplas, helix 3d by rundna, vicon, motion analysis corporation, qualisys, pro-trainer, xsens, and simi motion, while software like siliconcoach, kinovea, gaiton, dartfish, coach's eye, noraxon myoresearch, and shutter precision lack this functionality. Real-time feedback is supported by templo, helix 3d, dartfish, vicon, motion analysis corporation, qualisys, pro-trainer, xsens, simi motion, and noraxon myoresearch but is absent in siliconcoach, kinovea, gaiton, coach's eye, and shutter precision. Integration capabilities are present in most tools, including siliconcoach, templo, gaiton, dartfish, vicon, motion analysis corporation, qualisys, pro-trainer, xsens, simi motion, and noraxon myoresearch, but are notably absent in kinovea, helix 3d, coach's eye, and shutter precision. Finally, customizable reports are widely supported across nearly all software, providing users with flexibility in data presentation and analysis.

1.2 Discussion

Each software tool has its strengths and weaknesses, influencing its suitability for different use cases. For example, SiliconCoach and Kinovea are ideal for educational purposes and small-scale studies due to their ease of use and affordability. In contrast, tools like Vicon and Motion Analysis Corporation are best suited for high-stakes research and professional applications due to their superior accuracy and advanced features. Challenges encountered during the evaluation include the complexity of setup for high-end systems and the learning curve associated with advanced features (Akl et al., 2019; L et al., 2024). Also, cost and accessibility remain significant barriers to the widespread adoption of premium tools.

Performance Analysis

SiliconCoach: Known for its moderate processing speed, it is suitable for real-time analysis but is not as fast as high-end systems. It provides good data accuracy for general sports applications and has moderate hardware requirements, making it accessible to a wider range of users (Belete et al., 2024). Kinovea: This open-source software offers efficient video analysis with good accuracy for basic kinematic analysis. It requires low to moderate hardware resources, making it a highly accessible tool for both amateur and professional use. Templo by Contemplas: Templo offers high processing speed suitable for complex analyses, with very high data accuracy that meets professional standards. It requires high-end hardware, which can be a limitation for some users but is justified by its advanced capabilities (Widhalm et al., 2024). GaitON: It is designed for real-time gait analysis, providing high processing speed and accuracy. It has moderate hardware requirements and is user-friendly, making it suitable for both clinical and sports settings. Helix 3D by RunDNA: This software excels in real-time running analysis, offering high processing speed and precision. It requires moderate to high hardware resources and is designed for ease of use with detailed

tutorials. Dartfish: Known for its efficient video analysis, Dartfish provides good accuracy for general sports analysis with low to moderate hardware requirements. Its customizable interface enhances usability for both novice and advanced users. Coach's Eye (Mobile): This mobile-based tool offers fast processing for video analysis, suitable for general coaching purposes. It requires only a smartphone or tablet, making it highly accessible but less precise for detailed research. Vicon: Renowned for very high processing speed and exceptional sub-millimetre accuracy, Vicon systems are ideal for detailed biomechanical studies. They require high-end hardware and extensive training, which can be a barrier for smaller organizations. Motion Analysis Corporation: This advanced tool offers high processing speed and precision, suitable for complex motion analysis. It requires high-end hardware and professional training, making it best suited for high-end research and professional use. Noraxon myoResearch: Providing high processing speed and precision with advanced sensors, Noraxon myoResearch is reliable for both clinical and research applications. It requires specialized hardware and training, positioning it as a premium option. Qualisys: Offering real-time motion capture with exceptional accuracy, Qualisys systems demand high-performance hardware and professional training (Almeida et al., 2023). They are highly reliable and suitable for professional and research settings. Pro-Trainer: With moderate processing speed and good accuracy for general training analysis, Pro-Trainer has moderate hardware requirements and is designed for easy use by coaches and trainers.

SiliconCoach: Features a user-friendly interface focused on sports coaching, making it easy to learn and use for coaches and athletes. Kinovea: Boasts a highly intuitive and easy-to-navigate interface, suitable for users with varying levels of technical expertise. Its straightforward design and short learning curve make it accessible for detailed analysis. Templo by Contemplas: Offers a professional-grade interface with a steeper learning curve, requiring training to fully utilize its advanced features. GaitON: Known for its user-friendly and intuitive interface, GaitON is designed for easy use by individuals with minimal technical background, enhancing its accessibility. Helix 3D by RunDNA: This software is designed for ease of use with a professional and intuitive interface, supported by detailed tutorials that aid in maximizing its potential. Dartfish: Features an intuitive and customizable interface, catering to both novice and advanced users. Comprehensive tutorials and support resources enhance the user experience. Coach's Eye (Mobile): Mobile-friendly and easy to use, this tool is designed for quick and accessible analysis, suitable for users on-the-go. Vicon: While offering extensive features and customization options, Vicon's interface is complex and requires extensive training for full utilization. Despite the steep learning curve, it offers unparalleled functionality for detailed analysis. Motion Analysis Corporation: Provides an advanced and customizable interface, requiring professional training to operate effectively. It offers extensive capabilities for detailed biomechanical research. Noraxon myoResearch: Features a professional-grade interface that requires training to effectively use its comprehensive analysis tools, suitable for clinical and research applications. Qualisys: Known for its advanced and customizable interface, Qualisys requires professional training to use effectively, offering high functionality for professional and research settings. Pro-Trainer: User-friendly and accessible, Pro-Trainer is designed for easy use by coaches and trainers, facilitating straightforward training analysis.

Accuracy and Reliability

SiliconCoach: Provides accurate data for coaching purposes but is not as precise for detailed research. It is reliable for routine use in coaching environments. Kinovea: Offers reasonable accuracy for basic analysis, with reliable and consistent performance for its intended use. Templo by Contemplas: Delivers high accuracy for detailed biomechanical analysis and is highly reliable in professional settings. GaitON: Provides high accuracy for gait analysis, with reliable performance in clinical and sports settings. Helix 3D by RunDNA: Known for high accuracy in running biomechanics, Helix 3D is reliable for continuous use in training environments. Dartfish: Delivers good accuracy for coaching and performance analysis, with consistent performance across different sports. Coach's Eye (Mobile): Offers reasonable accuracy for coaching but is not suitable for detailed researcah. It is reliable for its intended use in coaching. Vicon: Industry-leading accuracy with sub-millimetre precision, Vicon systems are highly reliable for professional and research applications. Motion Analysis Corporation: High accuracy suitable for detailed biomechanical research, with reliable performance for extensive use. Noraxon myoResearch: High accuracy with advanced sensor technology, reliable for clinical and research applications. Qualisys: Provides exceptional accuracy for detailed analysis and is highly reliable for repeated and detailed use. Pro-Trainer: Offers

reasonable accuracy for training and coaching, with reliable performance for routine analysis. Enhancing integration capabilities and developing more user-friendly interfaces can also drive adoption and utility in various fields (Fatima, 2024; Nwafor et al., 2023).

4. CONCLUSION

This comparative study highlights the software tools available for kinematic analysis, each with unique features and capabilities. By evaluating these tools based on their performance, usability, accuracy, and cost, this article provides valuable insights for selecting the most appropriate software for different applications in sports science. The study suggests that all future software developers may focus on further dimension. Continuous technological advancements and user-centric design will further enhance the effectiveness and accessibility of kinematic analysis tools, contributing to the advancement of sports science and biomechanics. Future work should focus on improving the usability and affordability of advanced kinematic analysis tools, making them accessible to a broader audience.

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