Implementation of Sports Science and Technology Integration Infrastructure: A Case Study of Speed Skating Utilizing Web and Mobile Applications, and Information Visualization Technologies

Minkyu Kim and Soojung Park*

Dept. of Kinesiology, Inha University, Michuhol-gu 22212, Republic of Korea
E-mail: kmk@inha.ac.kr; psj@inha.ac.kr
**Corresponding Author*

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Abstract

In the field of sports, there is an active discussion on and an attempt to apply technologies that integrate sports with cutting-edge science and technology for the purpose of enhancing athletic performance. In line with this trend, South Korea is supporting research on the fusion of sports and science technology at an interdepartmental level. For the improvement of performance in elite sports, it is important to consider the athlete's skills, the coach's information analysis, the scientification of equipment, and the environmental optimization. Accordingly, this study aims to propose web and mobile app technologies to establish an integrated infrastructure of sports science and technology for the three factors of athletes, equipment, and environment to improve the performance of speed skating. Furthermore, it aims to make policy recommendations to activate this integration. The application of such technologies and policy recommendations can be transferred and organically

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integrated into other sports, including track and field, which are time-based competitions. Additionally, it is expected that this approach will lead to the formation of new theories that consider the emotional aspects occurring in sports situations.

Keywords: Speed skating, sports science and technology, convergence, infrastructure, web, mobile app.

1 Introduction

In 2011, Pyeongchang, Korea, was chosen to host the Winter Olympics, and the Korean Ministry of Science and ICT planned a policy project entitled 'Pyeongchang Korea Project' in order to develop core convergence technology based on fundamental research on convergence of sports and science technology. This policy project was carried out to support technologies optimized for the sports field through field-oriented convergence research based on technology demand. It was sought to apply science and technology to the three factors that are essential for sports: player, equipment, and environment [1].

Since 2015, the Korea Institute of Sport Science of Korea Sports Promotion Foundation has conducted a policy project to operate and support the hands-on sports science team for player performance enhancement specifically for the Winter Olympics events with financial support from the Ministry of Culture, Sports, and Tourism. The fundamental goal was to improve player performance and support sports science for the national teams in preparation for the Pyeongchang Winter Olympic Games [2]. Such policy projects aiming to improve player performance in the area of elite sports are closely connected with increasing awareness of the necessity for the scientification of training methods and develop modernized facilities among coaches and players [3]. Demands for IT-based training manuals and high-technology facilities are increasing among the elite sports circles.

In line with the basic policy direction for successful hosting of the Pyeongchang Winter Olympic Games, enhanced awareness in elite sports circles, and related demands, governmental departments of Korea decided to support the convergence of sports and science technology with a focus on selected game events that had advantages as the host or with high possibility of winning metals. Among Winter Olympic Games events, speed skating was

recognized as having a high possibility of winning metals as 3 gold medals and 2 silver medals were won in this event at the 2010 Vancouver Winter Olympic Games and 1 gold medal and 2 silver medals at the 2014 Sochi Winter Olympic Games, respectively. Accordingly, material support was provided to sports IT convergence projects for player performance improvement. To this end, the Korea Sports Policy Institute provided the national team of speed skating with feedback on problems and technical training through starting/curved course 3D motion analysis. For 3D motion analysis, 9 high-speed photographing cameras were used. These cameras were interconnected through BNC cable for synchronization, and the recording function was controlled by means of one trigger. As a result, the completeness of physical performance and skills was improved. In accordance with such support, South Korea secured 1 gold medal, 4 silver medals, and 2 bronze medals at the 2018 Pyeongchang Winter Olympics.

However, following the conclusion of the Winter Olympics held in the country, the budget and support experienced a slight reduction. Consequently, South Korea only managed to obtain 2 silver medals and 2 bronze medals at the 2022 Beijing Winter Olympics. After the conclusion of the 2018 Pyeongchang Winter Olympics, various factors such as the retirement of top athletes, budget cuts, and decreased policy support contributed to the decline in speed skating performance. However, the primary reason can be attributed to the enhancement and modernization of speed skating facilities in competing countries, leading to significant improvements in their athletes' performance.

In order to enhance player performance in the area of elite sports, harmonious support for players, equipment, and environment was essential. Unlike the basic policy direction of elite sports in Korea, however, support for environment was insufficient while there was support for players, equipment, and sports IT convergence. One major policy factor related to sports environment was to establish infrastructures [4]. Speed skating involves certain criteria of ice temperature, humidity, indoor temperature, etc. as it utilizes a stadium. Thus, this is one of the most appropriate events to which sports IT convergence infrastructures can be applied.

Accordingly, this study proposes technology to establish infrastructures for convergence of sports and IT with regard to three specific factors – player, equipment, environment – with the aim of improving player performance in the sport event of speed skating, and the policy recommendations are stated.

2 Body

2.1 Features of Speed Skating

Speed skating is an ice sport where two players on skates start and run on 400 m ice rink tracks. The 400 m-long course is divided into an inside lane and an outside lane. As a pair of players go around the track once, the player who starts from the outside lane goes into the inside lane in the designated crossing area, and the player who starts from the inside lane goes into the outside lane. As shown in Figure 1, a speed skating stadium presents a 40 0m track which consists of two straight sections and two curved sections. The men's speed skating events consist of 500 m, 1000 m, 1500 m, 3000 m, 5000 m, 10000 m, 1600 mR, 2000 mR, 3000 mR, and team pursuit (8 laps), while the women's events include 500 m, 1000 m, 1500 m, 3000 m, 5000 m, 1600 mR, 2000 mR, 3000 mR, and team pursuit (6 laps). The mass start was added based on the 2016 World Championships criteria, and the team sprint was incorporated according to the 2019 World Championships criteria [5].

The ice quality in the speed skating stadium affects speed skating games significantly. As the density level of ice is high, the surface is smooth with friction minimized. As a result, skate blades slip on it effectively. To secure such high-quality ice conditions and ice density, the stadium should maintain an ice temperature between 5 and 9 degrees below zero, an indoor temperature between 15 and 16 degrees, and humidity under 30%. In order to maintain the ice surface smooth, purified, clean water is used.

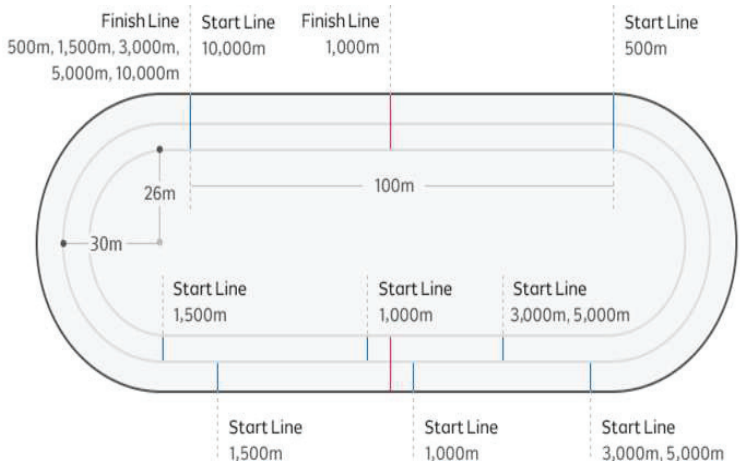

Figure 1 A speed skating stadium (refer to 2018 Pyeongchang Olympics website).

2.2 Application of New Bio-signals

Previous support for speed skating players' performance improvement focused on physical training in such ways as a motion load test, anaerobic power measurement, stamina measurement, nutrition intake, and so forth, and such support was aimed at determining proper exercise types, strength, frequency, and duration based on the quality and quantity of exercise suitable for the speed skating player's physical strength. This type of support for training purposes has limitations in that it fails to consider players' various needs and specific physical and psychological conditions and merely aims to provide one-way communication programs based on the speed skating player's physical strength and ability. This study aims to discuss the application of EEG technology among various biosignals[1] that indicate emotional changes during physical activity, enabling data collection and analysis through sports IT convergence support.

It is possible to gain a speed skating player's emotional and psychological states by applying this brain wave technology. According to Kim et al. (2016), brain waves are divided based on the range of frequency and voltage to delta, theta, alpha, beta, gamma, and so forth [6]. Among these, waves that are measurable in speed skating training are α, SMR, mid-β, β, and γ waves. As to the emotional and psychological states depending on the frequency, α waves indicate relaxation and rest; SMR waves attention; mid-β waves concentration and activation; β waves tension, excitement, and stress; γ waves intense stress out of anxiety and nervousness (refer to Table 1). According to the study conducted by Anderson et al. (2011), the utilization of electroencephalography (EEG) technology was employed to assess athletes' concentration levels and cognitive load. The findings indicate that during periods of high concentration, there is a tendency for alpha wave activity (8–12 Hz) to decrease, while beta wave activity (13–30 Hz) increases. For instance, analysis of EEG data collected during specific training sessions revealed a reduction in alpha wave activity by approximately 15%, whereas beta wave activity increased by about 20%. These results suggest a significant correlation between changes in EEG activity and the athletes' concentration levels and cognitive load [7]. As the brain wave technology is applied, it

[1]Biosignal technology refers to the measurement and analysis of various physiological signals produced by the body. For example, it includes monitoring and analyzing signals such as brain waves (EEG), heart rate (ECG), and muscle activity (EMG). These signals allow for real-time monitoring of the body's condition, enabling the assessment of physical performance or health status based on the data collected.

Table 1 Emotional and psychological state of the EEG

Frequency Range	Frequency Name	Characteristics
8–12	α waves	Relaxation and rest
12–15	SMR waves	Attention
16–20	Mid-β waves	Concentration and activation
21–30	β waves	Tension, excitement, and stress
30–50	γ waves	Intense stress out of anxiety and nervousness

is possible to measure and analyze brain wave frequency in speed skating training at each corner, which will be helpful in training players depending on their psychological and emotional states.

2.3 Information Visualization

In the area of elite sports, information visualization has been utilized mainly by coaches to enter a training program optimized for each player's profile so that each player puts on wearable devices and goes to the designated training equipment. The training equipment indicates the exercise strength and frequency to each player based on the inputs of the wearable device. While a player is being trained, information on his/her heart rate, blood pressure, etc. is transmitted to the monitor of the coach in real-time. This is one actual example of IoT application. The data collected by means of this technology is quite useful in the step of training design after exercise. During the exercise, however, bio-information and game play records are not available to players but only to the coach.

Once players can check information during training, they can obtain a lot of feedback throughout the training course. Particularly in games such as speed skating where speed records are of great importance, if players can obtain information on speed, lap time at each section, world records, one's own best record and goal in real-time, they can gain a lot of useful feedback [8]. In this regard, this study discusses sports IT convergence through real-time information visualization technology that makes it possible to refer to information efficiently during exercise.

According to Card et al. (1999), information visualization is defined as a computer-based and interactive visual representation of basic data for cognitive expansion [9]. Information visualization means, in other words, to extract significant information by means of graphic elements and to deliver it to users effectively. This technology represents data in graphical or pictorial formats to make it easier to understand. By visually depicting complex data,

it helps users grasp information more intuitively. For example, visualizing data through graphs, charts, and 3D models can maximize the effectiveness of training. Information visualization makes possible effective perceptive inference through intuitive cognition of information [10]. The information acquired in this process helps maximize players' performance, which is called 'recognized performance' [11].

Cossich et al. (2023) discussed the potential impact of information visualization technology on sports performance analysis [12]. According to their study, the use of data visualization enables coaches and athletes to monitor performance metrics in real-time, thereby facilitating the provision of more accurate feedback during training sessions. For example, by utilizing visualized data, the average reaction time of athletes was reduced by 0.5 seconds, leading to an overall improvement in training efficiency by approximately 10%. These findings suggest that information visualization technology could serve as a crucial tool in enhancing sports training and performance outcomes.

If visual information is provided to speed skating players in a training course by means of real-time information visual displays that adopt the information visualization technology, their recognized performance can be enhanced significantly. In addition, as speed skating stadium environments use quite clean water, it is possible to embody this real-time information visual display technology.

2.4 Sports Data Collection through a Digital Transformation Device

To establish trust-based sports data collection in the digital era, blockchain[2] and artificial intelligence (AI)[3] technologies are utilized. Although the utility and service availability of blockchain are significantly lower than those of centralized systems or general distributed systems, which process tasks

[2]Blockchain can be conceptualized as a mechanism that enables consistent ordering of events occurring within anonymous, asynchronous networks without the involvement of a central server. Blockchain possesses characteristics such as decentralization, strong resilience, tamper-resistance, irreversible data generation and distribution, and anonymity.

[3]AI is a technology that enables computer systems to mimic human intelligence. AI analyzes data and makes decisions through functions such as learning, reasoning, problem-solving, understanding, and perception. For example, machine learning, natural language processing, and image recognition are key AI technologies that enhance automation and efficiency across various fields.

through one or multiple systems, it offers the advantage of improving reliability through the iterative result matching of nodes [13]. This is based on foundational technologies such as hash functions, asymmetric encryption techniques, digital signatures, and hash puzzles. In an era characterized by information warfare, various issues, such as information monopolization, distortion, and data abuse, are emerging. Therefore, the legitimacy of decentralized internet protocols on platforms is being secured, and the utilization of blockchain is being proposed as an alternative. Blockchain can serve as a distributed file system (InterPlanetary File System: IPFS) and a new protocol that can be decentralized through peer-to-peer (P2P) connections [14, 15].

2.5 Supplementary System for Speed Skating Training in Utilization of Information Visualization

Players put on goggles with a RFID-based (radio-frequency identification) portable brain wave device and IoT wearable devices through which the heartbeat is checked constantly. Based on the transmitted data, the coach can monitor the current status of the player. The RFID device transmits data through the antenna-based wireless communication with information stored in a microchip. This cognition technology makes it possible to manage information on various objects through IC chips such as food, animals, things, and so forth.

In general, this system functions according to the theory of inductive coupling: As the conductor loop (short cylindrical coil) generates an AC magnetic field at a reading/writing device, the system starts operating with a fine current running over it. The intensity of this magnetic field is weakened as the measuring point is far from the central axis of the coil, or in other words, as the distance increases. A player's position information is transmitted at the same speed that the player moves through the remote RFID reader installed at the top of the stadium. This remote RFID reader collects information on the player's current speed, position, and travel distance through the RFID. Distance measurement by means of RFID technology is based on the size of signals transmitted between an antenna and tags. The size of a transmission antenna is decided based on the value of internal elements. It is necessary to maintain a proper distance from a player in consideration of such technical characteristics. In this manner, it is possible to grasp and trace a player's position in the stadium by extending the recognition distance through the RFID system of 915 MHz [16]. Figure 2 shows the process of collecting data during player training such as speed at each section, distance, position, and so forth.

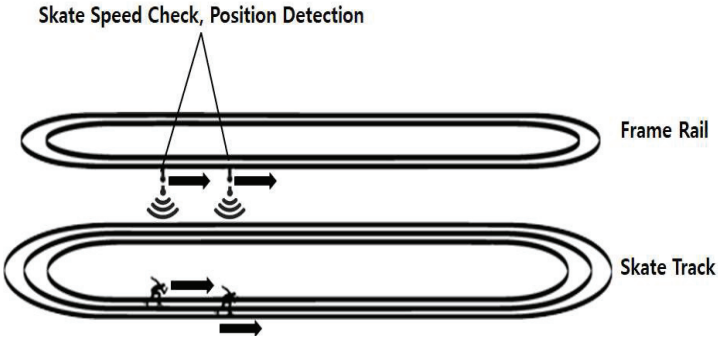

Figure 2 An example of RFID reader installation.

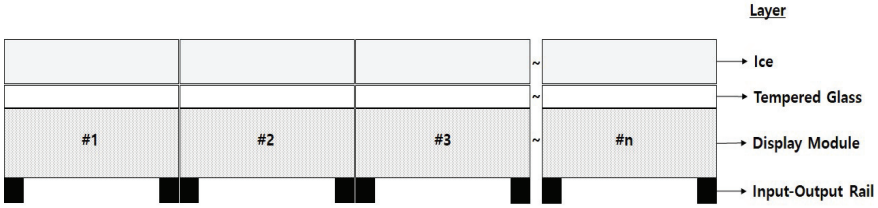

Figure 3 An example of multi-layered speed skating tracks in a stadium.

A display module is installed under the stadium track for information visualization, through which a player's training information on pre-set goals, world records, and one's best records is provided. The ice on speed skating tracks is 2.5 cm thick, and high intensity needs to be secured unlike for other ice games. For this reason, it is possible to protect the display panel and maintain sufficient visual effects as the ice is relatively thin. In order to prevent damage that results from an accident, transparent tempered glass that can secure durability and stability is installed in the middle. For installation and maintenance, a display rail that is easily detached is installed under the tempered glass. Facilities are built up over the entire track in the stadium. These details are summarized in Figure 3.

A display module controls device elements with unique numbers designated. Information is delivered from the computer to each display. Each display is also connected in parallel through network cables for smooth data transmission, as illustrated in Figure 4.

This display panel receives information transmitted by the computer in the format of RFID data values and displays it under the ice so that a player can see the information while running on the track, as shown in Figure 5.

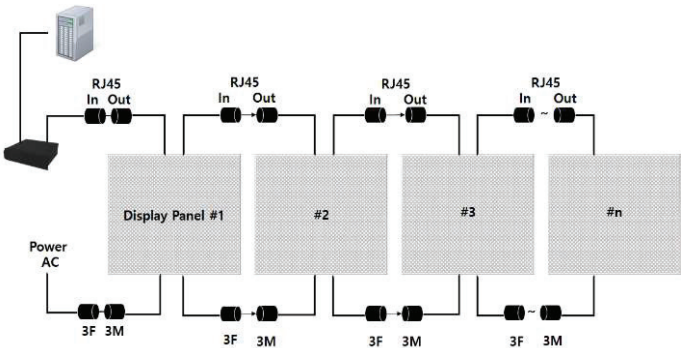

Figure 4 An example of display panel connection in parallel.

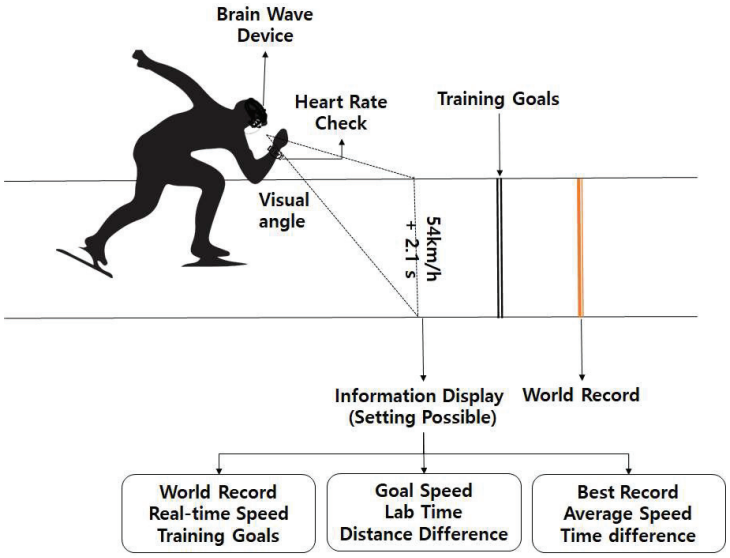

Figure 5 An example of information visualization.

The display is located at a visual angle at which a player can see the information. The visual angle may be adjusted flexibly depending on player characteristics. The displayed information may include the player's speed, world record, own best records, speed goal, and difference between the goal and actual record (speed, distance, etc.) according to the player's preference.

Humans are affected physiologically by optical characteristics such as color temperature, color rendering index, and spectra. Such physiological effects have been demonstrated through experimental measurements such

as brain waves and electrocardiogram [17, 18]. Thus, rather than a communication function that transmits information merely through signals, a psychological approach related to human emotions can make it possible to improve a player's performance by utilizing customized settings such as psychology-related colors (temperature, color rendering index, spectra, font, symbol, etc.).

This training system not only sets up a player's cognition factors but also needs a player's data in a director's perspective. It is possible to develop a training program based on the generated data so that game strategies can be planned in reflection of individual players' characteristics.

A player's psychological changes are grasped constantly during a training course or a game based on brain waves and heart rates. In addition to monitoring a player's emotional and psychological changes during a training course or throughout a game, it is also possible to check such changes at certain sections – start, straight lane section, curved lane section, and finish – in reflection of the unique characteristics of speed skating. Such monitoring aims to check and improve psychological conditions when a player achieves a high record or fails to do it. It is possible to develop programs to enhance player performance such as cardiovascular endurance training program in reflection of each player's psychological conditions.

Once bio-signals are embodied to an information visual display, various training modes can be developed and applied according to training goals. Bio-signal data including player position, brain wave, and heart rate are transmitted to the cloud server through indoor wireless transmission devices, and analyzed information is transmitted to the display controlling computer. In this manner, proper information at each position is transmitted and shown through each corresponding information visual display panel.

With the RFID-based positioning technology and real-time display of information at the player's visual angle, it is possible to overcome the psychological limit of a player and to develop psychological and physical training programs accordingly.

Additionally, an increased demand for high-quality sports data[4] is anticipated during the digital transformation era. Sports data is conceptualized as 'structured or unstructured information that exists in a machine-readable format, generated or processed through devices with information processing capabilities mediated by sports.' Classifications of sports structured data

[4]Based on Article 1, Clause 1 of the Act on the Promotion of Data-Based Administration.

include general characteristics,[5] game records,[6] physical information,[7] fitness information,[8] biometric information,[9] exercise performance information,[10] psychological information,[11] health information,[12] environmental information,[13] and physical information.[14] This also encompasses information on physical activity levels derived from algorithms using the aforementioned data [19, 20]. Sports unstructured data[15] can be categorized into pure sports content,[16] media sports content,[17] and sports business content.[18]

A trust-based system utilizing blockchain and AI is necessary to create, collect, process, utilize, and distribute the increasing demand for sports data. The following processes are involved: sports data generated by individuals are transmitted to data servers through various IoT technologies, such as wearable devices and smartphones. This sports data is encrypted anonymously at its source and shared with digital rights management rules. In this process, the sports data provider is protected through blockchain smart contracts to prevent usage beyond the allowed information and purpose.

[5]General characteristics can be composed of variables such as gender, age group, and sports performance level of elite athletes and recreational sports participants.

[6]Competition records are composed of variables reflecting the characteristics of each sport.

[7]Physical information can be composed of variables such as height, weight, muscle mass, skeletal muscle mass, and body fat percentage.

[8]Fitness information can be composed of variables such as muscle strength, muscle endurance, flexibility, cardiorespiratory endurance, agility, balance, and coordination.

[9]Biometric information can be composed of variables such as body temperature, sweating, heart rate, blood pressure, respiration, and brain waves.

[10]Exercise performance information can be composed of variables such as the type of exercise performed, the number of repetitions, and weight.

[11]Psychological information is composed of variables related to psychological states during sports performance, such as concentration, tension, anxiety, and arousal.

[12]Health information is composed of variables including various diseases and medical history of recreational sports participants, i.e., the general public.

[13]Environmental information can be composed of variables such as temperature, humidity, illuminance, and altitude.

[14]Physical information can be composed of variables such as three-dimensional motion information, position, distance, speed, and angular velocity.

[15]Unstructured data is based on Article 2, Clause 1 of the Content Industry Promotion Act and refers to "data or information such as symbols, characters, shapes, colors, sounds, acoustics, images, and videos (including their combinations) mediated by sports."

[16]Content that does not require media integration and has value as an event is centered on the characteristics of sports.

[17]Content that is indirectly relayed and reported through mass media and has copyright.

[18]Content that can be stored and distributed, and is linked to related industries, creating added value through the utilization and expansion of sports.

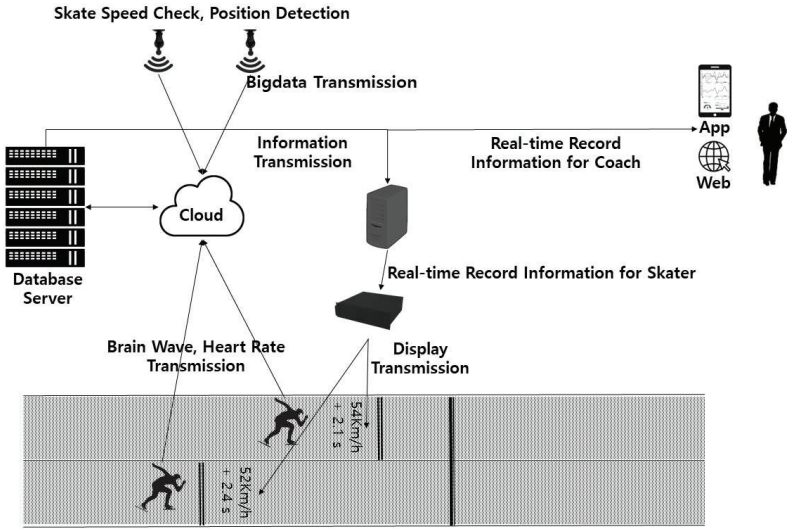

Figure 6 A diagram of the information visualization system.

This enables individuals to provide information within their permitted scope, allowing sports data consumers to access paid sports data, necessitating a tokenization process for the anonymity of sports data providers. The application of blockchain technologies, such as data derived and generated from the aforementioned processes, smart contracts,[19] and asymmetric encryption techniques,[20] can result in improved reliability as well as cost savings [21]. The composition of the finalized system that can be installed in a speed skating stadium is shown in Figure 6.

2.6 Implementation of a Web and Mobile App for a Speed Skating Training Support System

As previously discussed, speed skating is a sport where the accuracy and accessibility of real-time information is vital for both athletes and coaches. This section aims to describe the implementation of real-time information relayed to coaches with a focus on the characteristics and pros and cons of web and mobile apps, and to offer suggestions.

First, the fundamental characteristics of web and mobile apps are discussed. The web can be easily accessed through browsers and URLs, and

[19]Scope of sports data collection and utilization, etc.
[20]Passwords.

is often optimized for screens that are generally larger than those of mobile apps, making it relatively easier to handle complex diagrams or large amounts of information. Additionally, updates on the web are reflected immediately in the user's browser from the server side. Most web interfaces show limited access to the hardware functions of a device.

On the other hand, mobile apps are directly accessible by touching an icon after installation. The screen size is typically optimized for a mobile environment, which limits the amount of information that can be displayed. Updates require periodic downloading from app stores. A major advantage of mobile apps is their extensive functionality, as they can directly utilize features such as cameras, GPS, and sensors.

For the web platform, it is suggested to mainly encompass and structure detailed information and analysis of the real-time game records and information of the speed skating training system. First, there's the 'detailed game record' which analyzes the detailed records of each round and competition for each player. Second, the 'overall leaderboard' displays cumulative rankings and records of all participating athletes. Third, the 'player profile' presents comprehensive athlete information, including achievements and photos. Fourth, 'game analysis' consists of performance analysis graphs and comparison data for matches and individual athletes. Fifth, previous match and training videos are 'archived'.

For the mobile app, the emphasis is on real-time information provision and communication during training or games. First, the 'real-time game record' provides the current game's real-time time record and ranking. Second, the 'notification feature' checks and provides notifications on important matters such as the start of a game, record updates, and penalties. Third, it supports 'real-time communication' that allows live conversations between coaches and players or among coaches. Fourth, the 'mobile analysis tool' allows real-time analysis of player movements and performance using camera, GPS, and sensors. Fifth, the 'recording feature' uses QR codes or NFC for easy information access and updates.

3 Conclusion

This study proposes technology to establish infrastructures for convergence of sports and IT with regard to three specific factors – player, equipment, environment – with the aim of improving player performance in the sport event of speed skating. To this end, various technology factors have been combined and a training system has been developed with the aim of improving speed

skating players' performance. This study discusses the application of an information visual display panel that embodies brain waves which are new bio-signals and information visualization technology. Additionally, the use of blockchain and AI technologies for a trust-based system to generate, collect, process, utilize, and distribute sports data in the digital transformation era is also discussed.

Recent trends in sports science research emphasize the integration of neurotechnology, information visualization, and mobile applications to enhance athletes' training and performance. These technologies play a critical role in assessing and improving athletes' focus and stress levels in real-time, validating their practical applicability across diverse sports environments.

An example of this is found in the study by De Vos et al. (2014), which demonstrated the successful classification of real-time P300 components in EEG signals under outdoor conditions, including seated and walking scenarios [22]. This study achieved a classification accuracy of 69% (range 54–88%), significantly above the chance level. Additionally, Rydzik et al. (2023) reviewed 10 studies involving 491 participants in the neurofeedback group and 62 in the control group, finding that neurofeedback training effectively reduced stress levels, increased self-control over physiological factors, improved behavioral efficiency, and enhanced reaction times to stimuli [23]. These technologies enable tailored training programs and real-time feedback during the training process, significantly contributing to improving athletes' technical performance and strategic decision-making.

Furthermore, Legg et al. (2012) highlighted the importance of glyph-based visualization technology for real-time sports performance analysis in facilitating swift responses during games [24]. This system operates on tablet devices through applications and web platforms, providing an intuitive touch-based interface for easy data exploration and analysis. The system records events every 15 seconds during games, visualizing the success of each event with green or yellow circles, thus enabling quick decision-making during crucial moments. This visual feedback supports immediate responses to critical situations during games, aiding coaches and athletes in making fast and effective strategic decisions. This study underscores the practical applicability of glyph-based visualization in sports analysis and highlights its potential as a tool for optimizing performance outcomes.

As this technology is adopted to speed skating player training, it is possible not only to manage player records real-time but also to provide optimized feedback (two-way communication) in consideration of each player's physical and psychological states. This system is advantageous in that it overcomes

the limit of the existing custom that information is provided only to the coach in the training field and provides players with information so that they can check their own records real-time.

By discussing the approach of delivering real-time game records and information of the information visualization speed skating training system through both web and mobile apps, we have categorized and presented information for efficient speed skating coaching. Previous studies related to web and mobile apps in the sports field have mainly focused on the quality of sports website services based on PCs [25–27] or mobile devices [28]. This trend can be attributed to the fact that the consumption of sports through mobile devices primarily occurs via two platforms: mobile websites (e.g., visiting sports-related websites through web browsers pre-installed on smartphones) and mobile apps (e.g., downloading sports-related mobile apps to access sports information). However, despite research efforts on mobile sports consumption, there has been little to no research applying these two formats in the field of sports coaching, which is considered one of the most significant research areas in sports science, especially in terms of enhancing elite athletes' careers. This highlights the significance of this study.

However, the information visual display panel represents information not in images but only in texts. This system is designed to display texts based on existing studies because humans need to process a more cognitive load when images are given than when texts are given [29]. As this technology is embodied, the future study needs to examine the cognitive ability to process images or signals during a player's exercise in comparison with the cognitive ability to process texts.

Additionally, in order to activate this infrastructure, the following policy recommendations are proposed. First, enhanced inter-departmental cooperation is needed. A more integrated and coordinated approach among different departments and institutions (such as sports, technology, health, etc.) can facilitate the development and implementation of sports science technology infrastructure. Second, increased investment is required. Funding for research and development in sports science technology must be increased, accelerating technological advancements and enabling more comprehensive scientific analysis for athletic performance improvement. Third, training and educational support is necessary. Athletes, coaches, and other stakeholders need to be educated about the advantages of this technology, how to use it, and how to interpret the data it provides, thus ensuring maximum utilization of the infrastructure. Fourth, there is a need for the establishment and enforcement of regulations and standards. Appropriate regulations and

standards must be established and enforced to ensure the safe and fair use of sports science technology. Fifth, efforts to increase public awareness and promote public participation are required. Programs can be implemented to increase public awareness about the importance and benefits of sports science technology, and promoting public participation can lead to greater support and development of the sector.

The application examples and policy suggestions of this technology can be transferred and organically integrated not only in speed skating but also in other sports disciplines such as track and field and swimming. Furthermore, it is expected to form a new theory considering even the emotional aspects that occur in the exercise situation.

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References

[1] Kim, H.Y., 'Research on fusion of winter sports science base', *Industrial Engineering Magazine*, vol. 24, no. 1, pp. 21–28, 2017.

[2] Song, J.H., 'Pyeongchang winter olympics sports science support contents for speed skating', *Sports Science*, vol. 136, pp. 38–49, 2016.

[3] Junge, A., Engebretsen, L., Alonso, J.M., Renstöm, P., Marshall, S.W., Golighttly, Y.M., 'Sports injury and arthritis', *North Carolina Medical Journal*, vol. 68, no. 6, pp. 430–433, 2007.

[4] Kim, M.K., Song, J.R., 'An exploring on policy factor for revitalization of sports welfare', *The Korean Journal of Physical Education*, vol. 57, no. 3, pp. 263–279, 2018.

[5] Pyeong Chang Olympic Organization, 'Speed Skating Overview', 2018, Retrieved from https://www.pyeongchang2018.com/en/sports/speed-skating.

[6] Kim, M.K., Park, S.J., Park, B.K., Cho, Y.H., Kang, S.Y., 'A new paradigm for the spread sport leisure culture focusing on the IT-based convergence interactive system', *Lecture Notes in Electrical Engineering*, vol. 376, pp. 1477–1485, 2016.

[7] Anderson, E. W., Potter, K. C., Matzen, L. E., Shepherd, J. F., Preston, G. A., Silva, C. T., 'A user study of visualization effectiveness using EEG and cognitive load', In Computer graphics forum (vol. 30, No. 3, pp. 791–800). Oxford, UK: Blackwell Publishing Ltd. 2011, June.

[8] Ji, S.Y., Jung, M.A., 'Sports simulation system to improve competitiveness of elite athletes based on IT convergence technology', *Communications of the Korean Institute of Information Scientists and Engineers*, vol. 26, no. 12, pp. 18–22, 2008.
[9] Card, S.K., Mackinlay, J.D., Shneiderman, B., 'Reading in information visualization: Using vision to think', CA: Morgan Kaufman Publishers, 1999.
[10] Jang, S.H., Lee, K.W., Lee, J.Y., 'A study of information design methodology by comparative analysis between information visualization and knowledge visualization', *Design Convergence Study*, vol. 8, no. 2, pp. 19–30, 2009.
[11] Chung, J.E., Yook, D.W., Kim, B.H., 'The effects of psychological skills training on competitive state anxiety, performance of national figure skaters', *Korean Journal of Sport Psychology*, vol. 18, no. 1, pp. 33–55, 2007.
[12] Cossich, V. R., Carlgren, D., Holash, R. J., Katz, L., 'Technological breakthroughs in sport: Current practice and future potential of artificial intelligence, virtual reality, augmented reality, and modern data visualization in performance analysis', Applied Sciences, vol. 13, no. 23, 1–26, 2023.
[13] Lee, B.W., 'Bitcoin and Blockchain: The Reality of Virtual Assets 2nd Edition', Seoul: Acon, 2020.
[14] Kim, M.K. 'Issues and tasks of sports science technology convergence policy on the fourth industrial revolution: Focusing on future tasks and response strategies', *The Korean Journal of Physical Education*, vol. 58, no. 4, pp. 349–362, 2019.
[15] Park, Y.S., Glenn, Jerome C., 'The world future report 2035–2055', Gyeonggi: Kyobo Books, 2020.
[16] Yoon, C.S., Kim, T.I., Kim, H.J., Hong, Y.C., 'Indoor positioning using RFID technique', *Journal of the Korea Institute of Information and Communication Engineering*, vol. 20, no. 1, pp. 207–214, 2016.
[17] Jee, S.D., Lee, S.H., Choi, K.J., Park, J.K., Kim, C.H. 'Sensibility evaluation on the correlated color temperature in white LED lighting', *Journal of the Korean Institute of Illuminating and Electrical Installation Engineers*, vol. 22, no. 4, pp. 1–12, 2008.
[18] Lee, B.G., Hur, S.K., Yi, C.W., 'A study on sensitivity criteria of the LED lighting with a focus on preference evaluation of color temperature', Proceedings of Korean Institute of Illuminating and Electrical Installation Engineers Annual Conference, pp. 53–56, 2011.

[19] Kim, M.K., Park, S.J., and Park, B.K. 'A Study of Children Play Educational Environment Based on u-Healthcare System', *Lecture Notes in Electrical Engineering*, vol. 424, pp. 751–756, 2017.

[20] Kim, M.K., Park, S.J., and Park, B.K., 'A new paradigm for spectator sports in application of media', *Lecture Notes in Electrical Engineering*, vol. 514, pp. 115–121, 2018.

[21] Lim, H.J., Lee, M.S., Koo, W.Y., 'Design of blockchain-based space sharing economy scenarios', Proceedings of the Korean Institute of Electrical Engineers Conference, pp. 1776–1777, 2019.

[22] De Vos, M., Gandras, K., Debener, S., 'Towards a truly mobile auditory brain–computer interface: exploring the P300 to take away', International journal of psychophysiology, vol. 91, no. 1, 46–53, 2014.

[23] Rydzik, Ł., Wąsacz, W., Ambroży, T., Javdaneh, N., Brydak, K., Kopañska, M., 'The use of neurofeedback in sports training: systematic review', Brain Sciences, vol. 13, no. 4, 1–18, 2023.

[24] Legg, P. A., Chung, D. H., Parry, M. L., Jones, M. W., Long, R., Griffiths, I. W., Chen, M., 'MatchPad: interactive glyph-based visualization for real-time sports performance analysis' In Computer graphics forum (vol. 31, no. 3, 1255–1264). Oxford, UK: Blackwell Publishing Ltd., 2012, June.

[25] Carlson, J., and O'Cass, 'A Optimizing the online channel in professional sport to create trusting and loyal consumers: The role of the professional sport team brand and service quality'. *Journal of Sport Management*, vol. 26, no. 6, pp. 463–478, 2012.

[26] Hur, Y., Ko, Y.J., and Valaich, J., 'A structural model of the relationships between sport website quality, e-satisfaction, and e-loyalty'. *Journal of Sport Management,* vol. 25, no. 5, pp. 458–473, 2011.

[27] Suh, Y.I., Ahn, T., and Petersen, P.M., 'Examining the effects of team identification, e-service quality (e-SQ) and satisfaction on intention to revisit sport websites', *International Journal of Sport Marketing and Sponsorship*, vol. 14, no. 4, pp. 261–278, 2013.

[28] Ha, J.P., Chung, J.J., and Lim, C.H., 'Quality of a mobile sport website: Development and psychometric evaluation of a scale', *South African Journal for Research in Sport, Physical Education and Recreation*, vol. 39, no. 2, pp. 69–87, 2017.

[29] Ryu, J.H., 'Impact of picture and reading mode on cognitive load and galvanic skin response', *Science of Emotion and Sensibility*, vol. 13, no. 1, pp. 21–32, 2010.

Biographies

Minkyu Kim received his Bachelor's degree in Physical Education from Inha University in 2007, his Master's degree in Kinesiology from Inha University in 2009, and his philosophy doctorate degree in Kinesiology from Inha University in 2014. He is currently working as an Assistant Professor at the Department of Kinesiology, College of Art & Sport, Inha University. His research areas include sports science technology convergence R&D and convergence sport policy evaluation.

Soojung Park received her Bachelor's degree in Kinesiology from Ewha Woman's University in 1994, her Master's degree in Kinesiology from Ewha Woman's University in 1996, and her philosophy doctorate degree in Kinesiology from Ewha Woman's University in 2003. She is currently working as a Professor at the Department of Kinesiology, College of Art & Sport, Inha University. Her research areas include leisure convergence R&D and convergence leisure policy evaluation.