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Article

Exploring Barrier-Free Esports for Visually Impaired and Sighted Individuals: An Examination of Rapid Key Tapping Speed

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Abstract: Esports involves competition conducted through online computer games, a format that allows individuals to compete together regardless of age, sex, or physique. However, due to preconceived notions about individuals with visual impairments, their abilities are occasionally underestimated or overestimated. Furthermore, while esports heavily depend on visual elements, there has been little clarification on which abilities can be performed equally by both sighted and visually impaired individuals and which abilities differ. This study examined whether rapid tapping speed, a skill potentially utilized in esports, is affected by visual impairment, testing the hypothesis that there is no significant difference in tapping speed between visually impaired and sighted individuals. By identifying skills that show no differences and those that do, this research lays the groundwork for designing environments where all participants can equally enjoy activities, including the appropriate use of handicaps. The study employed a 30 s rapid tapping speed evaluation model in which participants were asked to tap a key on a computer keyboard as quickly as possible. The total number of taps, initial speed, and speed maintenance were measured over three trials, and temporal changes, such as deceleration, were assessed. No significant differences were observed between groups in the total number of taps, initial speed, or speed maintenance, indicating that tapping speed is not dependent on visual impairment. Thus, a rapid tapping ability can be equally demonstrated by both visually impaired and sighted individuals, highlighting the potential for increasing inclusivity in esports. These findings highlight the potential for creating inclusive esports environments that accommodate visually impaired players, thereby promoting broader participation.

Keywords: esports; visual impairment; rapid key tapping; inclusive gaming; barrier-free competition

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1. Introduction

Esports have recently undergone rapid global development, capturing the interest of a significant population, particularly among the younger generation. Esports involve online competitions conducted using computers or gaming consoles, where players control characters on a screen [1]. The International Olympic Committee, which has taken notice of the spread and development of esports, is exploring the possibility of including it as a new event in the Olympic Games [2]. Esports include various genres, ranging from virtual soccer matches to survival games in virtual environments, where numerous players compete to be the last surviving player. Esports can involve both individual and team battles. Players participate through the use of keyboards or game controllers while observing the screen, competing against opponents by displaying skill and strategy. One defining characteristic of esports is its inclusivity, allowing people of any age, sex, or physique to participate.

However, as esports strongly relies on visual elements and the use of screens, opportunities for visually impaired individuals to compete equally with sighted players remain limited despite occasional news of blind players successfully competing in esports. In this context, the development of barrier-free esports that can be enjoyed by both visually impaired and sighted individuals offers a crucial step toward a more inclusive society. Such initiatives would not only allow for the enjoyment of gaming by a larger population but would also foster interaction and understanding between visually impaired and sighted individuals. Furthermore, creating an environment where participants compete under the same rules would provide opportunities for appreciating and respecting one another's abilities, thereby advocating the importance of an inclusive society. The identification of universal skills that can be effectively utilized within esports settings regardless of visual capacity would be beneficial.

Research on universal skills required in esports is still limited. Studies on esports have primarily focused on its effects on the cardiovascular system and energy expenditure [3], cognitive functions [4–6], and reaction time [7,8]. However, studies on musculoskeletal abilities in esports are scarce. To explore new forms of competition, identifying gaming skills that do not rely on visual perception need to be identified. One such potential skill is key operation speed [9,10]. It is a vital operational skill in many fighting and shooting games and could serve as a competitive element for both visually impaired and sighted individuals.

To date, studies on finger movement speed have been conducted in various fields, such as neurophysiology [11,12], rehabilitation [13,14], and exercise science [15,16]. Factors affecting finger movement speed include age, sex [17], fatigue accumulation [14,15], and proficiency in activities such as piano playing [11]. Furthermore, differences in handedness [16], frequency of finger use, and the development of motor control [11] can influence tapping speed. However, few studies have examined the relationship between visual impairment and finger movement ability, making its impact unclear.

Research on the physical abilities of visually impaired individuals has mostly focused on aspects such as physical fitness [18,19], balance [20], and fingertip sensation [21]. Individuals who are completely blind develop posture control strategies that differ from those of sighted individuals [22]. Although some visually impaired individuals may have lower activity levels and muscle strength than sighted individuals, they frequently use their hands and fingers for tasks such as using a cane, reading in Braille, operating a computer keyboard, and inputting Braille on devices. Because the action of key tapping does not directly rely on vision, visually impaired individuals may have an equivalent or even higher finger-tapping ability than sighted individuals due to the increased use of their hands and fingers for communication and mobility.

In summary, existing research has provided critical insights into cognitive functions, reaction time, and physical fitness in relation to esports. While these studies highlight the importance of vision-dependent skills in gameplay, motor skills—particularly those with the potential to promote inclusivity for visually impaired individuals as universal abilities—have received insufficient attention.

There are often preconceived notions about individuals with visual impairments, such as the belief that their abilities are inferior or that certain abilities are exceptionally enhanced. These stereotypes can lead to their abilities being underestimated or overestimated, and such evaluations may not accurately reflect reality. This study examined whether the presence of visual impairments affects the skill of rapid tapping speed, testing the hypothesis that there is no significant difference in tapping speed between visually impaired and sighted individuals. By identifying skills that show no differences and those that do, this research not only provides insights into the capabilities of visually impaired individuals but also demonstrates the potential for inclusive esports environments where all participants can compete under equitable conditions, including the appropriate use of handicaps.

2. Materials and Methods

2.1. Participants

In this study, considering the limited number of visually impaired individuals, participants were recruited to the extent possible within educational institutions for visually impaired individuals. The sample size was not determined based on statistical criteria, as the study was conducted within the constraints of practical limitations.

Participants were selected based on the inclusion criteria: adult males who use a computer regularly in their daily lives and can type on a keyboard without difficulty, regardless of their visual abilities. The ability to perform touch typing was not required. Exclusion criteria included individuals with neurological disorders or conditions affecting hand or finger motor function.

This study enrolled 19 male volunteers, of whom 13 were visually impaired and 6 were sighted. This study was conducted using Japan's admission criteria for schools for the blind, defined as "corrected visual acuity of less than 0.3 (a visual field within 10 degrees)" to classify individuals with visual impairments. Individuals were further categorized as "low vision" if they were able to sign and "blind" if they were unable to sign. "Low vision" (as defined by the admission criteria) was assumed to involve some inconveniences in daily life due to visual impairment, whereas "blind" (unable to sign) was assumed to perform operations without relying on visual information.

When compared to the global classification of visual impairment (corrected visual acuity of 0.3 or less, visual field of 20 degrees or less), the definitions used in this study classified "sighted individuals" as having normal vision, "low vision" as corresponding to mild to severe visual impairment, and "blindness" as generally aligning with the global classification of blindness.

The mean age, height, and weight ($\pm$standard deviation) of the Blind group was 23.7 $\pm$ 2.1 years, 174.4 $\pm$ 3.4 cm, and 76.8 $\pm$ 5.9 kg, respectively. For the Low Vision group, the mean age, height, and weight were 30.2 $\pm$ 9.1 years, 171.2 $\pm$ 6.2 cm, and 66.2 $\pm$ 11.0 kg, respectively. The Sighted group had a mean age, height, and weight of 29.6 $\pm$ 5.7 years, 174.1 $\pm$ 5.1 cm, and 69.1 $\pm$ 11.7 kg, respectively. None of the participants reported a habit or proficiency involving frequent repetitive key tapping, such as that acquired in playing musical instruments or gaming.

2.2. Key Tapping Speed Evaluation Model

Tapping speed was evaluated using a 30 s key-tapping task. Tapping was performed with the left ring finger. The potential occurrence of fatigue was also evaluated. The utilization of the left hand for key tapping is intended to simulate the typical operational style in esports, with this study specifically focusing on the evaluation of musculoskeletal functions in keyboard operations. However, the tapping task is designed to assess the onset of fatigue resulting from repetitive tapping.

In esports, all fingers of the left hand are used, and situations occur where key operations with the left ring finger are required. However, the left ring finger generally has difficulty performing fine movements, and previous studies have described a slower tapping speed for this finger [11,17,23]. Furthermore, as the left ring finger is controlled only by the extensor digitorum muscle, it tends to fatigue more easily compared with other fingers, making it suitable for a load test. Therefore, key tapping was performed using the same finger throughout the task. The tapping duration implemented was based on a previous study that demonstrated the occurrence of fatigue and decreased tapping speed after >10 s of tapping [13,24]. Furthermore, the participants performed the 30 s tapping task three times to examine changes in tapping speed after a short period of rest.

Participants' handedness was determined through self-reporting. One participant identified as left-handed, while all others were right-handed. Due to the limited sample size, no statistical analysis based on handedness was conducted in this study.

2.3. Task Evaluation Protocol

The task involved tapping a computer keyboard key as quickly as possible from the start signal to the end signal within a 30 s interval. Prior practice was limited to a few taps performed during the explanation of the procedure. Participants were instructed to "tap as fast as possible from signal to signal", and no encouragement was given during the tapping task. The activity monitor displayed only the cumulative number of taps; no information about the elapsed time was provided. One trial consisted of a 30 s tapping session. Three trials were performed with a 1 min rest period between each trial. During the interval, participants were asked to let their arms hang naturally.

A left-handed keyboard (beri G30 membrane keyboard, buruberi, China) was connected via a Universal Serial Bus (USB) to a laptop computer. A custom palm rest, constructed from a 5 cm diameter plastic capsule toy lid, was placed at the edge of the keyboard to serve as an arm and palm support for the participant's left arm. The chair height was adjusted to enable the left arm to rest naturally on the armrest. The elbow was fixed in place with a towel to prevent it from lifting. The tapping key was selected based on the key (either "S" or "W") that felt most natural and easiest for the participant to tap repeatedly. Although the arm was not fully immobilized, participants were instructed not to lift their palms, wrists, or arms during the tapping task.

To record the input times, a custom program using JavaScript running on Google Chrome (version 90.0.4430.212) was used to ensure millisecond-level precision. In the system for recording tapping times, the first tap was designated as the zero-second reference point instead of using the researchers' start cue. Consequently, the duration from the start cue to the first tap was not recorded. The first tap was recorded at 0 s, and the following 30 s were designated as the tapping period. The average tapping speed was calculated by dividing the total number of taps performed during this 30 s period by 30 s.

2.4. Tapping Speed Data Analysis

The input time data were imported into Microsoft Excel for Microsoft 365 to calculate the total number of taps during the 30 s period and the number of taps per second, expressed in taps per second (Hz). The 30 s period was divided into 10 intervals of 3 s each, with the tapping speed for each interval calculated as the number of taps in 3 s divided by 3 s. Additionally, the trend of deceleration in tapping speed over time was evaluated.

The following evaluation items were calculated (Figure 1):

- Overall Average Speed: Total number of taps during the 30 s period divided by 30 s, providing an overall assessment of tapping ability.
- Initial Speed: The average tapping speed during the first 0–3 s, assessing an explosive start.
- Speed Maintenance: Indicates the rate of speed retention at each time point, assessing endurance.

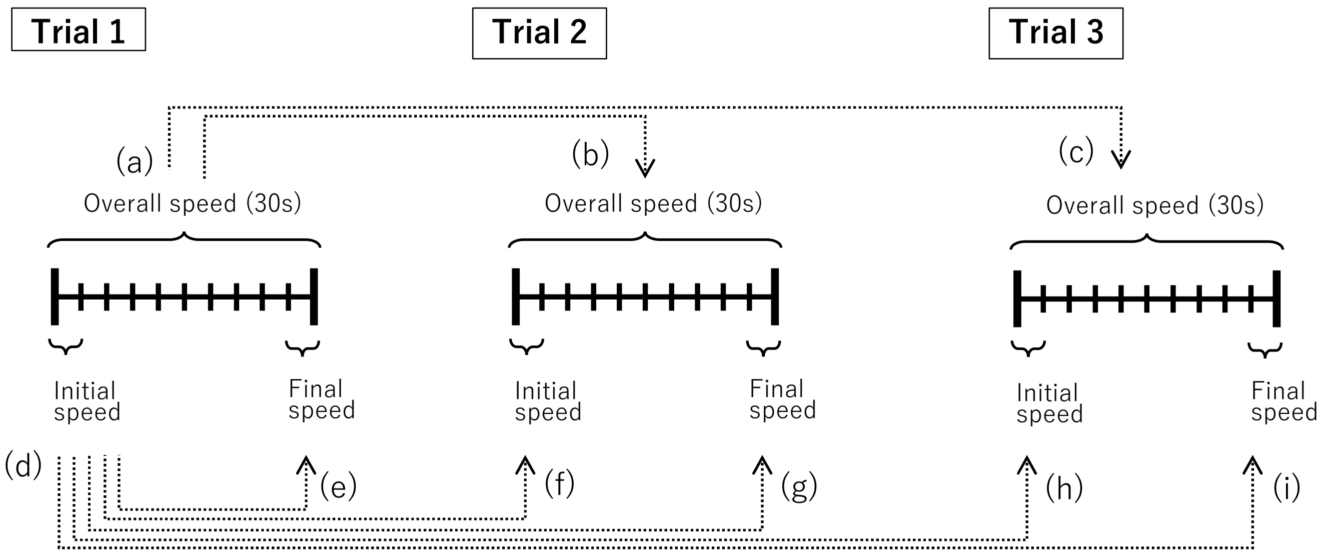

Figure 1. Conceptual framework of evaluation metrics.

The following nine points were compiled, with the letters corresponding to those in Figure 1:

(a) Overall Average Speed of 1st Trial (Hz)
(b) Speed Maintenance of 2nd trial = (2nd trial overall average speed)/(1st trial overall average speed) × 100 (%)
(c) Speed Maintenance of 3rd trial = (3rd trial final average speed)/(1st trial overall average speed) × 100 (%)
(d) Initial Speed of 1st Trial (Hz)
(e) Speed Maintenance of 1st final = (1st trial final speed)/(initial speed) × 100 (%)
(f) Speed Maintenance of 2nd initial = (2nd trial initial speed)/(initial speed) × 100 (%)
(g) Speed Maintenance of 2nd final = (2nd trial final speed)/(initial speed) × 100 (%)
(h) Speed Maintenance of 3rd initial = (3rd trial initial speed)/(initial speed) × 100 (%)
(i) Speed Maintenance of 3rd final = (3rd trial final speed)/(initial speed) × 100 (%)

2.5. Statistical Analysis

Data are expressed as the median and interquartile range. For items (a)–(i) above, comparisons between groups (Blind, Low Vision, and Sighted groups) were performed using the Kruskal–Wallis test to examine intergroup differences for non-normally distributed data. If a significant difference was found, the Mann–Whitney U test was used as a post hoc analysis to identify pairwise combinations showing significant differences. For pairwise comparisons between groups, the significance level was set at $p < 0.05$. The Bonferroni correction was applied to control for type I errors due to multiple comparisons.

3. Results

Table 1 presents the overall average tapping speed as well as the initial and final tapping speeds for each trial among the 19 participants.

Figure 2 shows the temporal changes in tapping speed across Trials 1–3 for the Blind, Low Vision, and Sighted groups.

Table 2 presents the results of tapping speed and speed maintenance for each group. Although no significant differences were observed between groups for most parameters, a significant difference was observed in "(i) Speed Maintenance of 3rd final" among the three groups (Kruskal–Wallis, $H(2) = 7.68$, $p = 0.021$). A post hoc analysis revealed a significant difference between the Blind and Low Vision groups ($p = 0.0471$).

Table 1. Results of tapping speed (n = 19).

	Overall Average Tapping Speed	Initial Tapping Speed	Final Tapping Speed
Trial 1	5.4 (5.2–5.7)	6.0 (5.5–6.7)	5.0 (4.7–5.3)
Trial 2	5.3 (5.1–5.5)	6.0 (5.3–6.3)	5.0 (4.7–5.0)
Trial 3	5.3 (5.2–5.7)	6.0 (5.5–6.3)	5.0 (4.7–5.5)

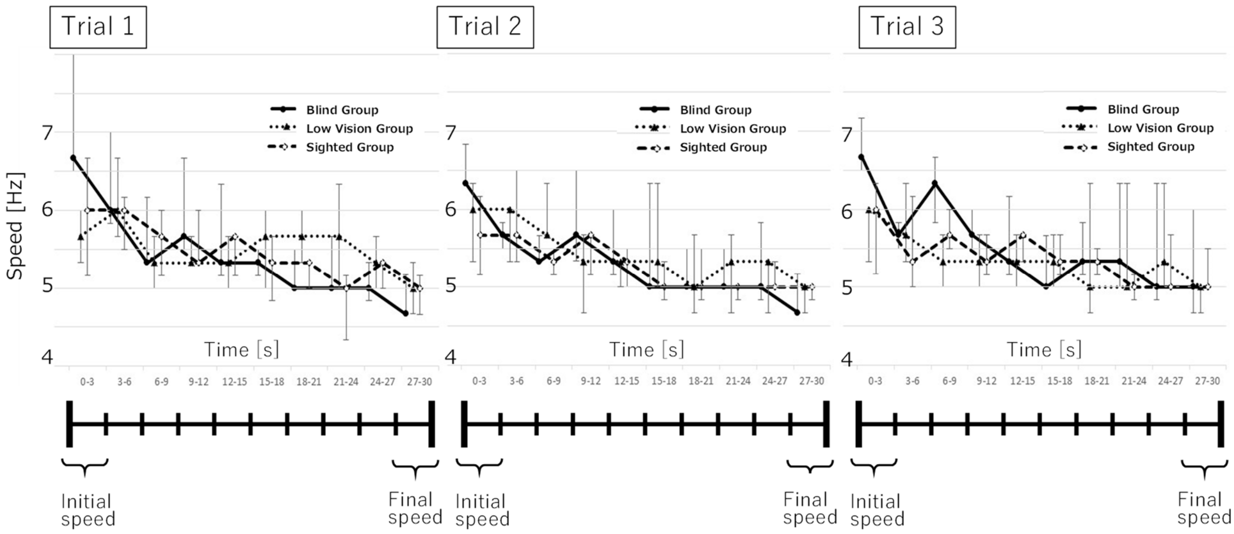

Figure 2. Time-course changes in tapping speed for Trials 1–3. Markers indicate median values, and error bars represent the interquartile range. The black circle, black triangle, and white circle represent the Blind (n = 3), Low Vision (n = 10), and Sighted groups (n = 6), respectively.

Table 2. Results of tapping speed and speed maintenance evaluation.

	Blind Group	Low Vision Group	Sighted Group	p Value
(a) Trial 1 Overall Speed	5.3 Hz (5.3–6.1 Hz)	5.5 Hz (5.1–5.8 Hz)	5.4 Hz (5.2–5.6 Hz)	0.852
(b) Speed Maintenance Ratio Overall Speed Trial 2/Trial 1	98.1% (96.4–98.8%)	99.4% (98.4–101.0%)	97.4% (99.4–102.2%)	0.711
(c) Speed Maintenance Ratio Overall Speed Trial 3/Trial 1	100.0% (100.0–100.3%)	100.0% (97.8–104.6%)	99.5% (99.5–105.7%)	0.974
(d) Trial 1 Initial Speed	6.7 Hz (6.5–8.0 Hz)	5.7 Hz (5.3–6.0 Hz)	6.0 Hz (5.2–6.7 Hz)	0.396
(e) Speed Maintenance Ratio Trial 1 Final Speed/Trial 1 Initial Speed	70.0% (65.4–71.9%)	82.0% (73.5–79.7%)	75.0% (70.1–87.4%)	0.231
(f) Speed Maintenance Ratio Trial 2 Initial Speed/Trial 1 Initial Speed	95.0% (86.8–97.5%)	100.0% (97.5–105.8%)	95.0% (103.0–113.5%)	0.054

Table 2. *Cont.*

	Blind Group	Low Vision Group	Sighted Group	p Value
(g) Speed Maintenance Ratio Trial 2 Final Speed/Trial 1 Initial Speed	70.0% (65.4–71.9%)	83.0% (67.7–79.1%	83.0% (83.0–98.0%)	0.068
(h) Speed Maintenance Ratio Trial 3 Initial Speed/Trial 1 Initial Speed	95.0% (88.5–100.2%)	100.0% (91.7–100.4%)	96.0% (102.9–114.5%)	0.773
(i) Speed Maintenance Ratio Trial 3 Final Speed/Trial 1 Initial Speed	75.0% (71.7–75.0%) *	88.0% (81.6–90.2%) *	83.0% (85.8–94.1%)	0.050 *

* Kruskal–Wallis test, H(2) = 7.68, $p = 0.021$. Post hoc analysis revealed a significant difference between the Blind and Low Vision groups ($p = 0.0471$). Data are expressed as median and interquartile range.

4. Discussion

Herein, we used a keyboard to evaluate fatigue during continuous tapping, assuming an esports context. Participants were instructed to tap as quickly as possible for 30 s. During the first trial, the tapping frequency decreased from an initial speed of 6.0 Hz to 5.0 Hz at the end. After a 1 min rest period, two additional trials were performed, which demonstrated similar patterns of decline.

We measured the tapping speed using a keyboard to evaluate fatigue associated with continuous tapping in esports. Research utilizing keyboards for this purpose has been limited. Previous studies on keyboard tapping include one conducted by Aydin et al. [25], who reported an average speed of 6.93 Hz for 20 s of tapping using the right index finger among right-handed male students. Ekşioğlu [17] measured the tapping speed of 18- to 85-year-old participants using eight fingers, excluding the thumbs, for 1 min. Although the results varied by age, sex, and finger used, the study recorded 5.12 Hz for the right index finger and 4.30 Hz for the left ring finger in 18- to 29-year-old men over a 5 s interval. Despite differences in devices, measurement methods, and participant motivation, no significant deviations in tapping speeds were observed.

Many studies have evaluated finger tapping speed using sensors, which is similar to keyboard tapping in terms of finger movements. These studies also reported the decline in tapping speeds over time. For example, Madinabeitia-Mancebo et al. [14] observed an increase in tapping speed for the right index finger from 5.7 Hz to 6.0 Hz over a 3 min period. Soto-Leon et al. [13] reported a decreasing trend in tapping speed from 5.73 Hz to 4.68 Hz using the dominant index finger for 3 min. Aydin et al. [25] also reported a decline in tapping speed over a 20 s tapping period, starting at 6.93 Hz.

Although commonalities and differences were found between sensors and keyboards, keyboards require a pressing action that may have a greater impact on fatigue and speed. Different types and weights of keyboard keys can influence fatigue; therefore, further research is needed to explore the effects of various keyboard characteristics. However, in the present study, which evaluated tapping using a keyboard, a similar decrease in tapping speed was observed over time, even with the left ring finger.

The effect of visual impairment on continuous tapping speed has not been previously investigated. The present study found no significant differences between the Blind, Low Vision, and Sighted groups in terms of the overall speed, initial speed, speed maintenance over time, and speed maintenance in repeated trials. These findings indicate that visually impaired individuals may possess similar capabilities as sighted ones in terms of both explosive power and endurance when performing continuous key tapping.

Overall, no significant differences were observed between the groups in terms of tapping speed and speed maintenance ratio. However, notably, the speed maintenance ratio of Trial 3 differed significantly between the Blind and Low Vision groups, with the Blind group exhibiting a significantly lower ratio than the Low Vision group. Although this result could be interpreted to indicate reduced endurance in the Blind group, several factors need to be considered. First, the speed maintenance ratio was calculated based on the initial speed in Trial 1, and a negative correlation was found between the initial speed and the maintenance ratio, indicating that the maintenance ratio decreased with an increasing initial speed. This finding implies that the Blind group may have adopted a strategy of tapping at maximum effort from the start, which caused a more pronounced decline in speed toward the end of the trial. This tendency aligns with the findings of Bächinger et al. [15], who reported that higher initial speeds result in a more significant deceleration during a 30 s tapping task. Therefore, the Blind group could maintain a speed comparable to that of the Sighted and Low Vision groups if their initial speed was appropriately moderated. Although the direct association between tapping speed and visual impairment remains unclear based on the current data, further investigation into differences in explosiveness, endurance, and overall speed strategies is warranted.

The present study found that the key-tapping ability of visually impaired individuals is comparable to that of sighted individuals, which is significant in challenging preconceived notions through empirical investigations. Visually impaired individuals tend to have lower overall physical fitness levels compared to their sighted counterparts, particularly in terms of muscle endurance and cardiorespiratory endurance [18]. However, they possess heightened tactile sensitivity that is developed through coping mechanisms involving tactile tasks [21]. Furthermore, visually impaired individuals differ from sighted individuals in their dynamic posture control. For instance, visually impaired judo players demonstrate greater lateral movement and variations in posture control ability and their dominant foot compared to sighted players, suggesting that visually impaired individuals may exhibit unique characteristics or habits [20]. The impact of visual impairment extends beyond directly vision-related motor functions, such as balance control with eyes open; it also affects other abilities, such as muscular strength and cardiorespiratory functions, due to limited opportunities for physical activity and exercise. Moreover, challenges in transportation and restricted access to fitness facilities can further reduce opportunities for physical training, thereby affecting physical capabilities. Additionally, movements that carry a risk of injury, such as brisk walking or jumping, or those requiring precise positional feedback, such as pegboard tasks, are likely to be influenced by experimental conditions. Therefore, the effects of visual impairment on various motor skills must be examined systematically to identify tasks that are affected by visual impairment. Visually impaired individuals may develop different movement patterns as they have little to no opportunity to imitate through sight. Although some abilities may be well-developed, others may not be. Key tapping, for example, could be a movement that visually impaired individuals excel at, struggle with, or perform at the same level as sighted individuals. In the present study, it was found that their key-tapping ability was comparable to that of sighted individuals.

Tapping speed is not merely an action; it has the potential for strategic application. For instance, a faster tapping speed could shorten gun reload times in combat games or enable quicker evasive maneuvers. Depending on the game design, tapping skills could become a decisive factor in determining victory. Incorporating such tasks would allow everyone, regardless of visual acuity, to leverage their strengths in the gaming scene.

The development of a gaming environment in which strategies that do not rely on vision can be utilized would be possible in the future, such as by adding features like a nighttime combat mode that limits visual information and conveys the enemy's position through sound or vibration. Such designs could provide a tense and exciting experience where visually impaired and sighted individuals can equally strive for victory.

The limited population of individuals with visual impairments and the scarcity of prior studies related to the indicators used made it difficult to set a statistically valid sample size. Therefore, data collection was conducted within the scope of an exploratory study. The findings of this study provide initial insights, and further large-scale research will be necessary to validate the results and enhance their generalizability. In this study, tapping was standardized using the left hand, reflecting common esports practices where keyboard operations are performed with the left hand. As a result, the findings may have favored left-handed participants. Future research should adopt designs that control for the effects of handedness to ensure more accurate evaluations.

Article 30 of the Convention on the Rights of Persons with Disabilities [26] encourages the participation of individuals with disabilities in sports, a responsibility that falls upon society as a whole. The results of this study provide insights that contribute to the development of competitions that can be enjoyed by both visually impaired and sighted individuals. The development of barrier-free esports is a crucial step toward realizing a more inclusive society that offers more opportunities for interaction and mutual understanding. By establishing an environment where everyone competes under common rules, we can expand opportunities for esports competitors to respect one another's abilities and appreciate the significance of a society in which everyone can participate meaningfully.

5. Conclusions

This study compared the key-tapping abilities of visually impaired and sighted individuals and found no significant differences in the total number of taps, initial speed, or speed maintenance. These results indicate that tapping ability is a skill independent of vision and can be performed regardless of visual acuity. The significance of this study lies in the actual examination of the relationship between visual impairment and motor ability. By leveraging elements that do not rely on vision, such as key tapping and adjusting other conditions, the development of an esports environment in which both visually impaired and sighted individuals can compete together can be possible. The findings of this study could serve as a reference for creating a competitive environment where visually impaired individuals can participate equitably.

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