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Original Article

The effect of static stretching on key hits and subjective fatigue in eSports

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Abstract. [Purpose] To explore the effects of static stretching for 20 s on key hits and subjective fatigue in an eSports-like setting. [Participants and Methods] The participants comprised of 15 healthy males who were instructed to hit a particular key on a computer keyboard using the left ring finger to achieve the maximum number of hits possible over a period of 30 s. Subjective fatigue of the forearm was assessed using a visual analog scale (VAS) before the experiment and after each trial. Trials 1, 2, and 3 were conducted in succession, with an inter-trial interval of 60 s to ensure a loaded state. Static stretching for 20 s preceded Trial 4. [Results] Over the first three trials, the number of key hits in the first 10 s gradually decreased, while the feeling of subjective fatigue gradually increased. After stretching, the number of key hits in the first 10 s of Trial 4 was similar to that observed in Trial 1, and there was no increase in subjective fatigue. [Conclusion] Static stretching for 20 s restored the number of key hits for 10 s after stretching to that before the load application and suppressed the increase in subjective fatigue.

Key words: Electronic sports, Static stretching, Finger movement

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INTRODUCTION

Electronic sports (eSports) involve competing in computer games and have become increasingly popular worldwide, with numerous professional players competing in tournaments that offer prizes exceeding hundreds of millions of dollars[1)]. In 2021, the global eSports market was valued at over $1.08 billion[2)], indicating that eSports players will likely play an active economic role.

Currently, eSports are played using a keyboard with the left hand and a mouse with the right hand. Using four fingers, the left hand principally operates the “W”, “A”, “S”, and “D” keys freely. The speed of key hits constitutes success in numerous gaming situations. However, some games require approximately 500 actions per minute[3, 4)], and the competition can continue for hours[3)]. Nonetheless, players are expected to make the desired key hits without reducing their number.

Researchers have investigated finger movement in a wide range of fields, including musical performance, computer operation, brain disorders, motor cortex function, motor ability, upper limb agility, and occupational science. Repetitive movements of the finger at the maximum speed cannot be sustained for long periods. Moreover, studies have reported that faster key hits reduce the number of hits within 30 s[5–7)]. However, these studies focused on the mechanism of finger movement rather than strategies for sustaining key hits. Furthermore, the maximum number of key hits possible and the effects of interventions on eSports performance remain unknown.

Notably, some eSports players have retired due to physical or mental health concerns[8, 9)], and there have been reports of musculoskeletal complaints[10)]. Gamer’s thumb is the common term for the diagnosis of de Quervain’s tenosynovitis from repetitive use of the thumb. The prevalence rates of tennis elbow, golf elbow, and carpal tunnel syndrome have also increased among gamers[11, 12)], and these injuries may end up earning a new name related to gaming similar to gamer’s thumb, as e-sports become more and more popular.

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In physical sports, overuse injuries result from the cumulative process of repetitive microtrauma and the overload of the musculoskeletal system, which causes tissue damage. Therefore, these injuries may have long-term negative consequences that decrease an athlete's performance[13]. During piano performance, which exhibits similarities to the keystrokes used by gamers, muscle fatigue is considered a risk factor for developing muscle-related muscular disorders and decreased performance ability[14]. The body gets stressed under such conditions and requires daily care.

Static stretching is widely practiced by both athletes[15] and office workers[16]. Stretching exerts positive effects such as an increased range of motion (ROM) and aids in preventing injury[17]. However, it has some negative effects, such as temporary decreases in maximum muscle power[18, 19–21]. Researchers believe that static stretching may limit body's ability to react quickly. The condition may last up to two hours in activities such as vertical jumps, short sprints, balance and reaction speeds. Thus, given its impact on performance, static stretching is not usually recommended for competitive gaming. However, the consequences of the acute effects of static stretching exercise on fatigue remain contradictory[22–25]. Indeed, some authors have argued that there are no adverse effects of static stretching if the exercise duration is within 30 s, although the exact mechanism underlying this phenomenon is not well understood.

Stretching is sometimes mentioned as a care option in eSports. Nonetheless, whether static stretching affects the number of key hits remains unknown. As this type of stretching can be performed within a short duration between competitions and exercises, further reports regarding its effects will aid in the development of guidelines for its incorporation in eSports. Therefore, we aimed to investigate the effect of static stretching for 20 s on the number of key hits and subjective fatigue while performing continuous key hits in an eSports-like setting.

PARTICIPANTS AND METHODS

This study included healthy adult men who had not received any special training. Their mean age, height, and weight were 30.1 ± 8.1 years (21–51 years), 171.5 ± 6.1 cm, and 67.4 ± 10.4 kg, respectively. None of them played computer games or used their hand excessively on a daily basis.

This study was approved by the University of Tsukuba Human Ethics Committee (East 2020-84). Written informed consent was obtained from all participants.

We used a laptop computer as the test device. A one-handed keyboard (beri G30 buruberi, China) was connected to the computer via a universal serial bus. Moreover, we attached a hemisphere with a diameter of 5 cm as a palm rest at the position where the palm was placed.

A computer program written in JavaScript (Google Chrome version 90.0.4430.212, Mountain View, CA, USA) and run in a browser was used to record the time point when the key was pressed. The current number of key hits was displayed on the screen. However, the time was not displayed.

The task was performed with a room temperature between 20.3 °C and 22.1 °C, and the participants were seated at a desk with a monitor and keyboard. The height of the chair was adjusted such that the elbows could be comfortably placed on the armrests while the shoulders were naturally lowered (slightly abducted). Participants placed their left hand on the keyboard. If their carpals touched the desk, their palms were placed on the palm rest. Moreover, their elbows were lifted from the armrests and adjusted with a towel such that they could not be lifted. They chose a key that their fingers could press at an angle that naturally arced and pressed that key during the task.

The key was to be hit repeatedly with the left ring finger. The ring and little fingers reportedly have a slower key hit speed than the index and middle fingers[26, 27]. In addition, while making a key hit, individuals use the flexor muscles that lower the finger and the extensor muscle that raise the finger. Nonetheless, unlike the little finger, only the extensor digitorum muscle acts on the ring finger, which is the result of the right hand. Of the four fingers, the ring finger has been described as the most difficult to operate[27]. In addition, a single finger and two fingers can keep hitting a key and alternate keys, respectively, at different speeds[27], and various key-hit patterns exist. The trial involved making a key hit immediately using the left ring finger only, which would in turn increase the burden on the finger within a short span.

We instructed the participants to hit the keyboard at a maximum speed for 30 s, in order to obtain the maximum number of key hits possible. No interventions, such as encouragement, were provided during the task. Despite not being fixed, the elbows, wrists, and palms could not be lifted.

The 30-s trial was performed four times (Trials 1, 2, 3, and 4). We provided an interval of 60 s between each trial, during which the keyboard was released and the arm was drooped. During Trials 1, 2, and 3, a sufficient load was applied without intervention. Subsequently, a stretch intervention was applied between Trials 3 and 4.

Before and after each trial, participants were asked to report their subjective feelings of fatigue of the forearm extensor and flexor muscles using a visual analog scale (VAS) consisting of a 100-mm straight line. While the left end indicated "no fatigue", the right end indicated "maximum fatigue imaginable".

While participants used one of their fingers to perform key hits, muscles such as the extensor digitorum were used to release the finger from the button. The extensor digitorum superficialis is more susceptible to muscle fatigue than the flexor digitorum superficialis in typing work[28], and piano key hits with similar movements are associated with signs of fatigue in the extensor rather than in the flexor[14]. Considering that the load on the extensor muscles was high for key hits, we decided to implement static stretching for the extensor muscles of the forearm.

The static stretching intervention was performed with the aid of a licensed masseuse. Briefly, the elbow joint was extended in the sitting position, and the forearm was in the pronated position. The fingers and the wrist joint were flexed. The forearm extensor was slowly stretched without recoil and held for 20 s at a comfortable tension.

The start time denoted the time when the first key was pressed following the start signal. The number of key hits was defined as the number of hits per second and was denoted in Hz. The 30-s duration of each task was divided into 10-s periods (three periods in total). We calculated the average number of key hits every 10 s. The number of key hits in the first 10 s increased from Trial 3 (under load) to Trial 4 (after stretching), we defined that stretching was effective. Values are presented as mean ± standard error. Excel and SPSS26 (IBM Corporation, Armonk, NY, USA) were used for the statistical analyses. Moreover, we performed paired t-tests, with the significance level set to 5%. Correlations between variables were analyzed using Pearson's product-moment correlation coefficients.

RESULTS

Table 1 summarizes the changes in the number of key hits and subjective fatigue of the forearm. The number of key hits significantly decreased after 10 s during the 30-s trial. The number of key hits in the first 10 s was similar in Trials 1, 2, and 3, following which it gradually decreased. After stretching, the number of key hits in the first 10 s of Trial 4 was approximately similar to that of Trial 1. Moreover, the decrease in the number of key hits during the 10–20-s period was equivalent to that in Trials 1 and 2, while the number of key hits during the 20–30-s of Trial 4 was lower than that in Trial 3.

VAS scores for subjective fatigue of the forearm extensor and flexor increased significantly after Trial 2 when compared to those after Trial 1, while those after Trial 3 increased significantly when compared to those after Trial 2. While there was no significant difference in the scores after Trials 3 and 4, we observed a significant difference in scores after Trials 2 and 4. Therefore, the VAS scores after Trial4 did not increase from after Trial 3, but did not decrease to after Trial 2.

Individual results showed that 7 people were effective in stretching and 8 people were not effective in stretching. Comparing the two groups, the number of key hits in the first 10 s of Trial 1 was greater in the effective group than in the ineffective group (Table 2).

VAS scores for subjective fatigue of effective group increase significantly after Trial 3 when compared to those after Trial 2, but was no significant difference in the scores after Trials 1 and 2, Trials 3 and 4, Trials 2 and 4. Therefore, the VAS scores after Trial 4 did not increase from after Trial 3, and decreased to the point where there is no difference from after Trial 2. In contrast, the in effective group did not significantly change the VAS score throughout the entire trial.

DISCUSSION

In the present study, we examined the number of key hits and the effect of static stretching for 20 s on subjective fatigue while performing continuous key hits in an eSports-like setting. Key hits were performed at a rate of approximately 6 Hz in the first 10 s of Trial 1, which gradually decreased to approximately 85% of this level after 30 s to. The number of key hits in the first 10 s gradually decreased during subsequent trials ($P<0.05$, no significant difference). The number of key hits in the

Table 1. Changes in the number of key hits and VAS scores for subjective fatigue (n=15)

	Number of key hits				**VAS scores for subjective fatigue**	
	0–10 s	10–20 s	20–30 s		Forearm extensor	Forearm flexor
				Before Trial 1	8.3 ± 3.7	2.7 ± 0.8
Trial 1 (30-s key hit)	6.01 ± 0.30 Hz	5.55 ± 0.21 Hz^{**1}	5.13 ± 0.19 Hz^{**1}			
60-s (VAS fillout, intermission1)				**After Trial 1**	17.7 ± 4.9	13.6 ± 5.1
Trial 2 (30-s key hit)	5.83 ± 0.25 Hz	5.37 ± 0.23 Hz^{**1}	5.17 ± 0.16 Hz^{**1}			
60-s (VAS fillout, intermission2)				**After Trial 2**	21.5 ± 5.0^{*a}	16.9 ± 5.7^{*b}
Trial 3 (30-s key hit)	5.73 ± 0.26 Hz	5.55 ± 0.22 Hz^{*1}	5.41 ± 0.25 Hz^{**1}			
60-s (VAS fillout, 20-s stretching)				**After Trial 3**	27.4 ± 6.4^{**c}	22.3 ± 6.1^{**d}
Trial 4 (30-s key hit)	6.01 ± 0.29 Hz	5.39 ± 0.21 Hz^{**1}	5.33 ± 0.25 Hz^{**1}			
				After Trial 4	26.9 ± 6.4^{†e}	20.7 ± 6.7^{†f}

^{**1}: $p<0.01$, ^{*1}: $p<0.05$ (compared to Frequency of key hits Trial 1 (0–10 s)), ^{*a}: $p<0.05$ compared (compared to VAS After Trial 1), ^{*b}: $p<0.05$ compared (compared to VAS After Trial 1), ^{**c}: $p<0.01$ compared (compared to VAS After Trial 2), ^{**d}: $p<0.01$ compared (compared to VAS After Trial 2), ^{†e}: $p<0.05$ compared (compared to VAS After Trial 2), ^{†f}: $p<0.05$ compared (compared to VAS After Trial 2).

first 10 s gradually decreased to 96.8% and 94.3% in Trials 4 and 3, respectively.

Despite differences in the fingers used and the conditions requiring movement, previous studies have reported that fingers can be moved at approximately 4–7 Hz[5–7, 26, 27], and that the number of key hits decreases to 80–90% of the initial level within 30 s [5–7]. The number of key hits observed in the present study is in accordance with these previous results.

Repetitive actions that require the utmost voluntary effort such as the bench press and squat result in an unintentional decrease in speed as fatigue develops[29]. Moreover, repetitive movements performed at the maximum rate cannot be sustained for long[30], with the rate decreasing beyond the first 10 s. Studies regarding the deceleration of key hits have not only examined the influence of muscle fatigue but also the excitatory involvement of spinal motor neurons and M1 inhibitory interneurons. The latter are involved in movements that are rarely observed in physical sports (i.e., no load and high frequency). The involvement of these neurons may explain decreases in the rate of repetitive movements and an inability to sustain key hits at the intended speed in eSports.

In Trials 2 and 3, the decrease in the number of key hits gradually increased. Although we did not verify the specific mechanism underlying this decrease, factors such as fatigue, habituation, and the proficiency effect may have been involved.

Out findings also indicated that subjective feelings of fatigue significantly increased in Trials 1, 2, and 3. Based on previous studies[16, 28], we expected the forearm extensor to fatigue more quickly than the forearm flexor. However, there was no significant difference between the forearm extensor and extensor, and the values changed at almost similar levels. Given that only subjective data were used to assess fatigue, further details remain unknown, necessitating further studies.

The decrease in the number of key hits within the first 10 s of the trial was considered to reflect load accumulation. The observed increases in subjective fatigue also support this notion. However, following stretching, the number of key hits in the first 10 s increased in Trial 4, despite similar reports of subjective fatigue for Trials 3 and 4. Interestingly, the number of key hits in the first 10 s of Trial 4 was similar to that observed in Trial 1, and the decrease observed after 10 s was comparatively smaller than observed in Trial 3. This finding suggests a temporary recovery of performance ability for the first 10 s after stretching.

Individual results indicated that, while some participants performed stretches effectively, others did not. The effective group exhibited a large number of key hits and reported considerable subjective fatigue (Table 2). In contrast, the ineffective group produced fewer key hits and reported less subjective fatigue. Moreover, the number of key hits fluctuated <10 s after initiation. In other words, participants who were tired and produced only a small number of key hits experienced no negative effect, while those who were tired and produced a large number of key hits may have experienced a recovery effect. Static stretching may not only reduce fatigue but may also improve reaction speed in eSports players capable of producing a high number of key hits.

Table 3 summarizes a comparison among studies that examined the acute effects of static stretching over the last

Table 2. Changes in the number of key hits and VAS scores for subjective fatigue in the effective (n=7) and ineffective (n=8) stretching groups

		Number of key hits				VAS scores for subjective fatigue	
		0–10 s	10–20 s	20–30 s		Forearm extensor	Forearm flexor
					Before Trial 1	7.7 ± 3.8	3.5 ± 1.1
						8.9 ± 6.4	2.0 ± 1.1
Trial 1	**Effective**	6.57 ± 0.50	5.99 ± 0.34^{*2}	5.54 ± 0.25^{*2}			
(30-s key hit)	**Ineffective**	5.51 ± 0.26	5.18 ± 0.17	4.78 ± 0.21^{**3}			
60-s (VAS fillout, intermission 1)					**After Trial 1**	25.5 ± 7.4	24.5 ± 9.6
						10.8 ± 5.7	4.1 ± 1.7
Trial 2	**Effective**	6.13 ± 0.48	5.79 ± 0.42^{**2}	5.54 ± 0.26^{**2}			
(30-s key hit)	**Ineffective**	5.56 ± 0.19	5.00 ± 0.16^{*3}	4.85 ± 0.10^{*3}			
60-s (VAS fillout, intermission 2)					**After Trial 2**	28.1 ± 7.9	27.9 ± 10.5
						15.7 ± 6.1	7.2 ± 3.6
Trial 3	**Effective**	5.94 ± 0.54^{*2}	5.93 ± 0.41	5.99 ± 0.42^{*2}			
(30-s key hit)	**Ineffective**	5.55 ± 0.16	5.23 ± 0.13	4.91 ± 0.15^{*3}			
60-s (VAS fillout, 20-s stretching)					**After Trial 3**	37.5 ± 10.2^{*g}	34.7 ± 10.7
						18.5 ± 7.1^{*h}	11.5 ± 4.3
Trial 4	**Effective**	6.60 ± 0.52	5.70 ± 0.39^{**2}	5.84 ± 0.46^{**2}			
(30-s key hit)	**Ineffective**	5.50 ± 0.15	5.11 ± 0.17	4.88 ± 0.12^{*3}			
					After Trial 4	37.5 ± 11.7	33.5 ± 12.6
						17.6 ± 4.9	9.5 ± 3.0

^{**2}: p<0.01, ^{*2}: p<0.05 (compared to Frequency of key hits Trial 1 (0–10 s)), ^{**3}: p<0.01, ^{*3}: p<0.05 (compared to Frequency of key hits Trial 1 (0–10 s)), ^{*g}: p<0.05 compared (compared to VAS After Trial 1), ^{*h}: p<0.05 compared (compared to VAS After Trial 2).

Table 3. Studies regarding the effects of acute static stretching conducted over the last 5 years

	Participants	Comparison	Muscle stretched	Stretching duration	Outcome	Effect (*: positive effect)
Palmer, 2019 [31]	15 young men, 15 old men	Before-After	Hamstring	8 min	Stiffness	Decreased *
Palmer et al., 2019 [32]	13 young healthy females	Before-After	Hamstring	30 s	Isometric peak torque (PT)	No difference
				60 s	Peak EMG amplitude (PEMG)	No difference
				120 s	Rate of torque development (RTD)	Decreased (120 s)
					Rate of EMG rise (RER)	Decreased (120 s)
Nakao et al., 2019 [33]	14 healthy young men	Before-After	Hamstring	5×1 min	Passive stiffness	Decreased *
					Range of joint motion (ankle plantar-flexed)	Increased *
Kataura et al., 2017 [34]	18 (9 male; 9 female)	Before-After	Hamstring	180 s	Static passive torque (SPT)	Decreased
					Range of motion (ROM)	Increased *
					Passive joint (muscle-tendon) stiffness	Decreased *
					Passive torque (PT) at onset of pain	Increased
					Isometric muscle force	Decreased
Hatano et al., 2018 [35]	24 healthy volunteers	Before-After	Hamstring	300 s	Static PT (passive torque)	Decreased
					Passive stiffness	Decreased *
					PT at the onset of pain	Increased
					Range of motion (ROM)	Increased *
Bogdanis et al., 2019 [36]	16 elite-level male gymnasts	Contralateral limb	Quadriceps	3×30 s	Countermovement jump height (CMJ)	Increased *
					Range of motion (ROM)	Increased *
				90 s	Countermovement jump height (CMJ)	Decreased
					Range of motion (ROM)	Increased *
Nakamura et al., 2020 [37]	16 healthy men	Before-After	Gastrocnemius	10×30 s	Range of motion (ROM)	Increased *
					Stiffness (shear elastic modulus)	Decreased *
Nojiri, 2019 [38]	15 healthy men	Before-After	Gastrocnemius	4×30 s	Shear elastic modulus	Decreased *
Sekir et al., 2019 [39]	23 male athletes	Control (no SS)	Peroneus longus Peroneus brevis Tibialis anterior	4×30 s	Reaction time	No difference
Ameer & Muaidi, 2018 [40]	60 female university students	Control trial SS or no SS	Quadriceps Hamstring Gastrocnemius	3×45	Reaction time	Decreased *
Avloniti et al., 2016 [41]	40 trained male athletes	Control trial SS or no SS	Hip extensors Hip adductors Knee extensors Knee flexors Ankle sole flexors	2×10 s 3×10 s 4×10 s 6×10 s	Speed (10-m and 20-m sprint) Agility (t-test)	Increased * (2×10 s) No difference
Panza et al., 2017 [42]	17 healthy college-aged adults	Control (no SS)	Flexor hallucis brevis	3×30 s	Cramp threshold frequency (CTF)	No difference

5 years[31–42]. We searched for articles in the PubMed database in July 2021 and extracted 12 comparative studies examining the acute effect of "static stretching" from 36 documents with "static stretching" in their title.

Stretching of the hamstring, quadriceps, and gastrocnemius exerted similar effects such as increased ROM and decreased passive muscle stiffness. However, the isometric muscle force decreased and the torque changed, depending on the conditions, although some studies reported a positive effect of such stretching on countermovement jump height under certain conditions. Other studies reported that stretching to the lower limb muscles improved both reaction time and speed. Nonetheless, stretching to the flexor hallucis brevis did not change the cramp threshold frequency, and some studies reported that static stretching exerts negative or no effects on muscle strength[18, 19] (Table 3). Thus, findings from the numerous studies on the lower limb muscles remain contradictory, although few studies have examined the influence of static stretching on these parameters in the upper limb muscles.

The present study had a few limitations. This is the first study to explore the effects of stretching on eSports performance. Although we investigated the effects of a static stretch lasting 20 s, further studies are required to verify whether the time of 20 s is optimal, and whether the results differ depending on the load conditions. Given that the effect of dynamic stretching has attracted attention in recent years, further studies are also required to identify the most effect type and timing of stretching.

In conclusion, the present findings indicate that the 20-s static forearm stretch performed in this study unloaded the muscles and allowed for high-frequency finger movements. Furthermore, the number of key hits performed within the first 10 s immediately after stretching was restored to that observed during the first trial. These results suggest that static stretching should be incorporated into short breaks during long eSports competitions, and that players can develop strategies for improving their key-hit speed via effective static stretching. Future studies should aim to clarify the optimal methods of stretching and promote recommendations for stretching as part of the self-care routine for eSports players. These studies should involve individuals with national qualifications (e.g., physiotherapists, masseurs) and specialists such as athletic trainers to further demonstrate the effects of appropriate static stretching on eSports performance.

Funding and Conflicts of interest

None.

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