Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

# TEST REPORT Nr. 2023 E/1

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| **Project name** | Testing activities of "Technology Business Centre" PROTOTECH program prototype according to the agreement No 10.1-3.3-3SL-2022/3 concluded between the Investment and Development Agency of Latvia, RSU, and Mr.Ģirts Ozoliņš regarding Grindclaw ™ ergonomic glove testing<br>("Tehnoloģiju biznesa centrs" programmas PROTOTECH prototipa testēšanas aktivitātes atbilstoši noslēgtajam līgumam starp Latvijas investīciju un attīstības aģentūru, RSU un Ģirtu Ozoliņu par Grindclaw™ ergonomiskā cimda testēšanu Nr. 10.1-3.3-3SL-2022/3) |
| **Customer:** | SIA "Grindclaw", Piladzu street 18, Pinki, Babites pag., Babites nov., LV-2107 |
| | /title, address/ |

# I. Methodology

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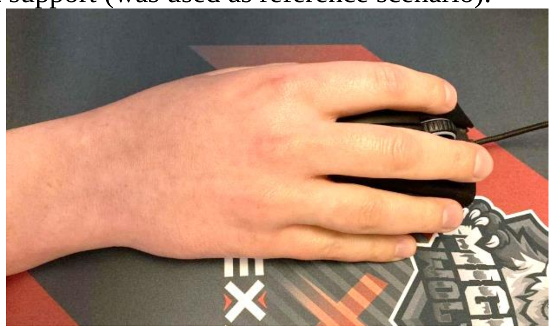
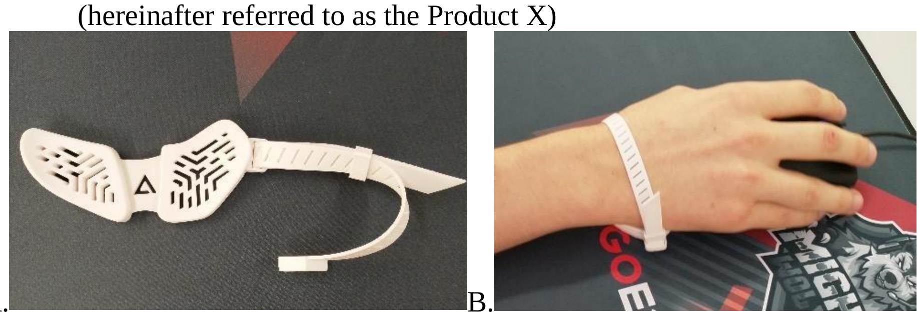
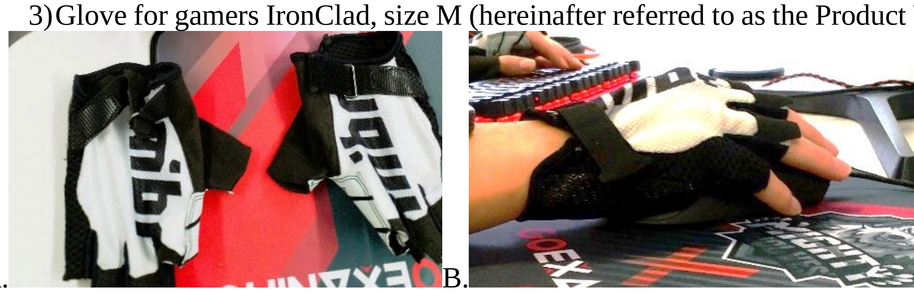
| **Tested objects:** | 4 scenarios were tested: |
| | 1) Playing with a bare hand and standard horizontal computer mouse without specific wrist support (was used as reference scenario).<br><br>**Figure 1.1. Playing with a bare hand and standard horizontal computer mouse** |
| | 2) Ergonomic wrist support for computer users Carpio G 2.0, size M (hereinafter referred to as the Product X)<br>A.  B.<br>**Figure 1.2. Ergonomic wrist support Carpio G 2.0 (A) and the process of testing Carpio wrist support and standard computer mouse (B)** |
| | 3) Glove for gamers IronClad, size M (hereinafter referred to as the Product Y)<br>A.  B.<br>**Figure 1.3. Gloves for gamers IronClad (A) and the process of testing gloves IronClad (B)** |

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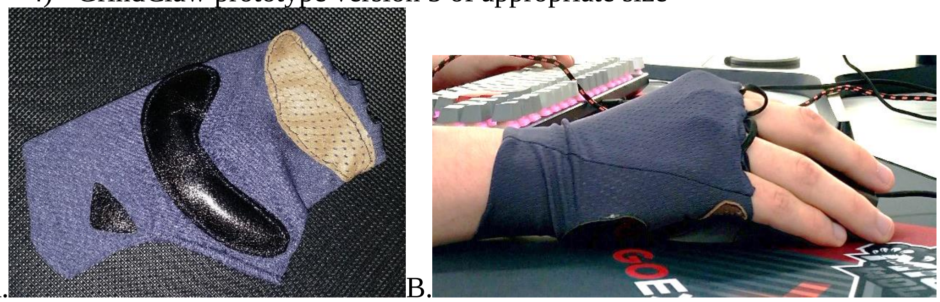
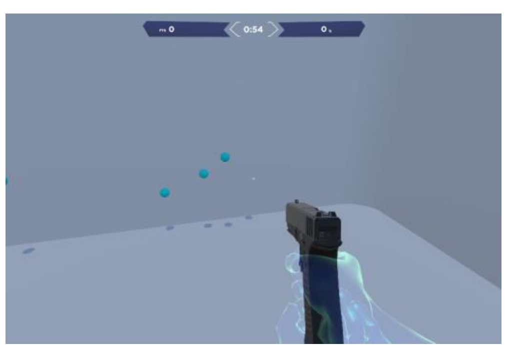
| | 4) GrindClaw prototype version 5 of appropriate size<br>A.  B.<br>**Figure 1.4. GrindClaw glove prototype v5 (A) and the process of testing GrindClaw prototype v5 (B)** |
| | The data from all the tested scenarios was compared between tested scenario as well as to the process of playing with a bare hand and standard computer mouse without any wrist support. |
| **Measurement site and time:**<br>- place, address | RSU Institute of Occupational Safety and Environmental Health, Laboratory of Ergonomics, Rātsupītes Street 5, Riga |
| - period | 08.09.2022.-12.10.2022. |
| **Testing methods:** | 4 methods of testing were used for every evaluated scenario: |
| | 1) **Manual dexterity test** by AimLab program (Statespace, 2018) using 6 standardised tests (3 runs of every 1-minute-long test) following each other at the beginning of the testing day and at the end of the 3rd hour of playing, adding 15 minutes breaks after each hour, and repeating 4 ergonomic scenarios on different days in 4 esports professionals (one person and one set of tests per day). The same computer mouse and mouse mat were used in all of the tests.<br>6 standardised dexterity tests were used:<br>● AngleShot<br>● FourShot<br>● Suavetrack<br>● Blinktrack<br>● Swayswitch<br>● Dodgeswitch<br><br>**Figure 1.5. Screenshot of the playing during the AngleShot test (AimLab)** |

2) **Wrist skin moisture test.** Skin moisture (TEWL – TransEpidermal Water Loss) of the palm, wrist basement and dorsal surface of the wrist was measured by Tewameter TM 300 to assess how breathable the gloves and other products for gamer's wrist are. The measurements were taken before the playing, at the end of every hour, then after the 15-minute-long break and after 3 hours of intensive playing immediately after the removal of the glove.


**Figure 1.6. Wrist skin moisture testing process with Tewameter (A. on the volar (palmar) surface of the wrist; B. on the wrist basement; C. on the dorsal surface of the wrist)**

3) **Soft tissue compression and microcirculation test.** Medical high resolution digital infrared thermal camera (ICI ETI 7320 Pro) with specialized program for thermal imaging analysis (IR Flash Medical Version 2.14.14.4.) was used to detect the compression of soft tissues and blood microcirculation in the wrist while using various products for gamer's wrist during 3 hours of intensive playing adding 15 minutes breaks after every hour. Thermograms were taken at the beginning of the test day (in 4 standard projections), at the beginning of playing, then every 15 minutes of playing, after 15 minutes break, and at the end of testing (in 4 standard projections). As area of interest (Figure 1.8), the dorsal surface of the 4th and 5th finger and lateral surface of the proximal third of forearm in right hand were set. Mean temperature of the skin in every area of interest was calculated. Soft tissue compression sites were evaluated visually on thermograms, comparing tested scenarios to each other.

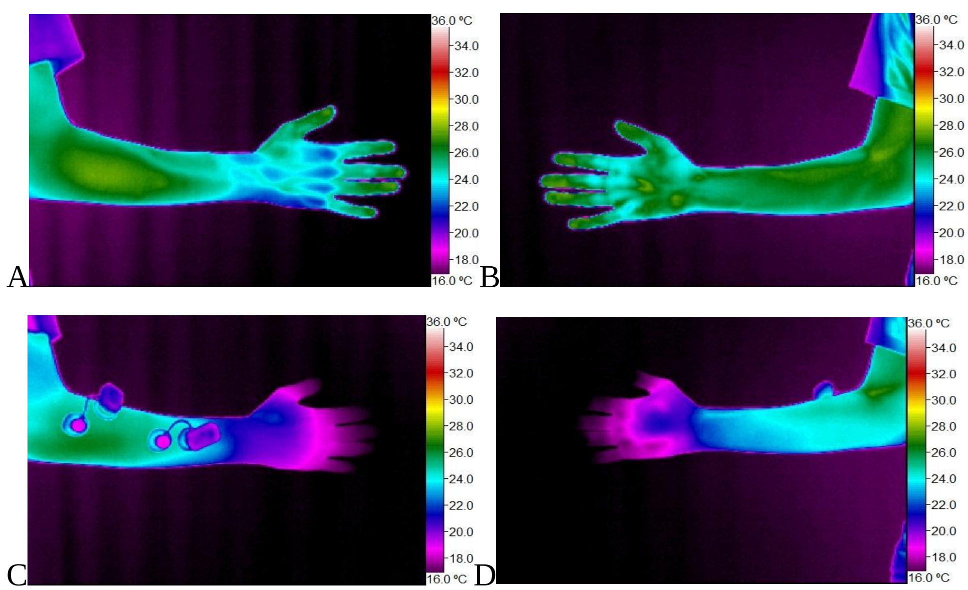



**Figure 1.7. Infrared digital thermal images indicating lower arm skin temperature before and after 3-hour-long gaming and GrindClaw use in standard environmental conditions (first row: before the test A. dorsal surface, B. volar surface of the lower arm and wrist; second row: after 3 hours C. dorsal surface, D. volar surface of the lower arm and wrist; colour scale on the right side shows corresponding temperature, ºC)**

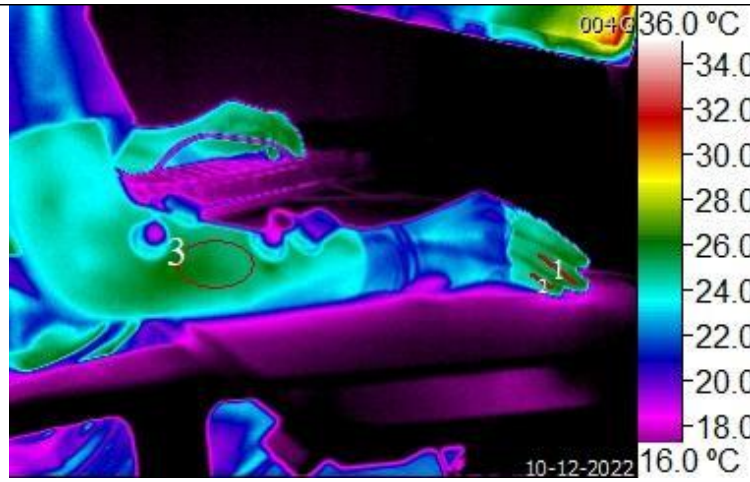
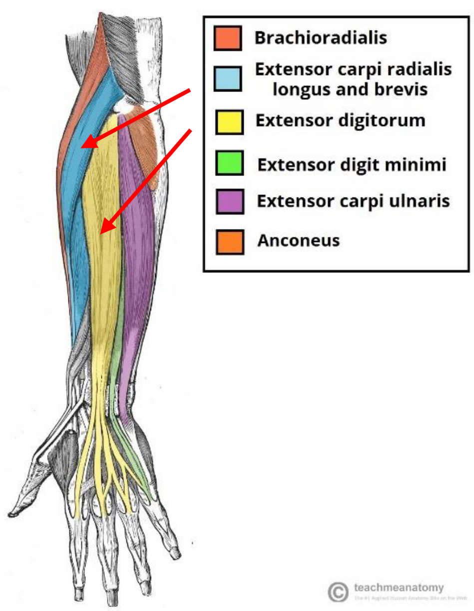



**Figure 1.8. Infrared digital thermal image showing areas of interest where mean temperature measurements were completed (area 1 – distal dorsal surface of the 4th finger; area 2 – distal dorsal surface of the 5th finger; area 3 - lateral surface of the proximal third of the right forearm)**

4) **Muscle electric activity test.** Surface electromyography (sEMG) of extensor carpi radialis longus muscle and extensor digitorum muscle bilaterally while playing 6 standard dexterity tests and a computer game.

A.



B.


**Figure 1.9. A. Extensor group muscles of the left forearm; B. Position of sEMG electrodes on extensor carpi radialis longus muscle and extensor digitorum muscle**

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|---|---|
| | Initially, the skin was prepared so as to improve the quality of signal. Hair was shaved at least one day before the tests. Skin was cleaned with alcohol pads immediately before attaching the electrodes. Electrode attachment site was identified by real-time electromyography and maximal force test. Electrodes were attached after the initial thermography and skin moisture measurements to avoid the influence of manipulations on other measurement results.<br>At the beginning, maximal force test was applied to every specific muscle and maximal possible EMG activity was recorded to calculate later the percentage of actual electric activity (effort) from maximal possible electric activity in a muscle. In every specific dexterity test, 15-seconds-long sEMG record was fixed not informing the tested person about the exact moment of recording (to avoid psychological effects on testing results). For analysis of muscle electric activity, the 10-seconds-long fragment was excised, and mean voltage and impulse frequency was calculated for every muscle tested. |
| **Testing devices:** | 1) High performing computer with installed programs for testing:<br>● AimLab (Statespace, 2018),<br>● computer game LOL (League of Legends), and<br>● CS:GO (Counter-Strike: Global Offensive).<br>2) Tewameter TM 300 (Courage + Khazaka electronic GmbH).<br>3) Medical high resolution digital infrared thermal camera (ICI ETI 7320 Pro) with specialized program for thermal imaging analysis (IR Flash Medical Version 2.14.14.4.).<br>4) Surface electromyograph BTS FREEMG 1000 with wireless electrodes (BTS Bioengineering) and a signal processing computer program BTS EMG-Analyzer provided by the manufacturer. Recording rate 1000 Hz. |
| **Equipment:** | ● Hight adjustable desk<br>● Hight adjustable ergonomic office chair with hight adjustable elbow supports<br>● High performing computer with installed programs for testing<br>● Keyboard<br>● Standard horizontal computer mouse for gamers<br>● Standard flat mouse mat<br>● Computer program AimLab (Statespace, 2018) with 6 standard manual dexterity tests for gamers (1 minute long every test)<br>● Computer game LOL (League of Legends)<br>● Computer game CS:GO (Counter-Strike: Global Offensive)<br>● Computer programs IBM SPSS Statistics for Windows and Microsoft Excel were used for statistical data analysis<br>● Disposable gel electrodes<br>● Alcohol pads for skin cleaning before application of the electrodes<br>● Electronical hygrometer/thermometer for checking the environmental conditions |
| **Study design:** | The **aim** of the testing was to clarify which type of the wrist support can provide minimal load for lower arm muscles, better microcirculation and least compression of the soft tissues in the wrist, better ventilation of the skin and improving of dexterity while playing computer games. |

Four different scenarios were tested under controlled environmental laboratory conditions and the results achieved were compared to the effect of playing just with horizontal computer mouse and flat mouse mat without any padding. For each scenario there was different type of wrist support and cover of the wrist. The testing was performed in the same environmental conditions and setup, only scenarios (products under test) were changed every day. The same computer mouse and mouse mat were used in all trials. A single scenario was tested in one gamer on each given day.

4 healthy right-handed esports professionals (2 men and 2 women) without any hand functional problems participated in the testing. One man and one woman played League of Legends game during the tests, another two played Counter-Strike: Global Offensive game. Every gamer participated for 4 days in 4 trials (different scenario on every day). Participants were informed about the course of the study before the tests. Written instructions about the preparation for the study were given several days before the study. All study participants have signed informed written consent. Participation was voluntary, all the participants had the right to quit the study at any moment.

Inclusion criteria for study participants:

1) Voluntary consent to tests,
2) Normal body mass index (without obesity),
3) Healthy (without pain in hands, without previous history of hand injury, without lesions in wrist and forearm skin, no fever on the day of the test),
4) Good experience and performance in playing computer games.

**The course of the testing:**

1) adaptation to room temperature, standing calmly for 10 min (arms along the body without squeezing anywhere);
2) thermography (marked: before) for both hands in 4 positions, in the upright position;
3) measurement of the skin moisture (marked: before) of the right wrist skin in 3 points;
4) preparing of the skin and attachment of sEMG electrodes, checking the muscle signal by real-time EMG, max force test (recording);
5) putting on a glove and accommodation for seating in front of the computer;
6) thermography (beginning, palm on computer mouse), manual dexterity test (3 runs of 6 tests) with recording of sEMG in the process of testing;
7) thermography every 15 minutes (at 15th, 30th, 45th minute and at the end of the 1st hour);
8) measurement of the skin moisture (mark: after 1 hour);
9) the 1st 15-minutes-long break;
10) measurement of the skin moisture (marked: after the 1st break);
11) sitting down at a computer, thermography (marked: after the 1st break, palm on computer mouse), sEMG recording (while playing computer game);
12) thermography every 15 min (at 15th, 30th, 45th minute and at the end of the 2nd hour);
13) measurement of the skin moisture (marked: after the 2nd hour);
14) the 2nd 15-minutes-long break;

15) sitting down at a computer, thermography (marked: after the 2nd break, palm on a computer mouse);
16) thermography every 15 minutes (at 15th, 30th, 45th minute and at the end of the 3rd hour) and last 30 minutes – manual dexterity test (3 runs of 6 tests) with recording of sEMG while testing;
17) removing the glove, immediate thermography for both hands in 4 positions, in the upright position (marked: after);
18) measurement of the skin moisture (marked: after the 3rd hour);
19) sEMG recording of maximal force test;
20) removal of electrodes.

# II. Testing results

## 1. Results of manual dexterity tests

Manual dexterity tests allowed to analyse the effect of different ergonomic products on wrist fine motor function of the gamers under standardized conditions. The analysis was performed in comparison with neutral condition, i.e., playing the same tests with the same computer mouse and mouse mat, but without any other additional product for wrist support. To investigate the dexterity, only one product was changed in various tested scenarios with all the other conditions remaining unchanged.

Standardized dexterity tests have shown that different products affect certain movements and dexterity in various ways (Figure 2.1.). Each dexterity test had a specific volume of score, for these reasons, the absolute numbers should not be directly compared between dexterity tests, but they can be compared within each test by tested scenario. More detailed analysis of each test by scenario and by measurement time is given in Figures 2.2A-2.2G. Analysis of the test results by tested scenario, test type and study participant ID is given in Annexes 1–4.

The summary of mean total score by tested scenario and dexterity tests is given in Table 2.1.

**Table 2.1**

**Summary of dexterity tests by tested scenario and dexterity tests (mean total score ± standard deviation and percent of change from the score in playing with a bare hand)**

| Scenario tested / Dexterity test | Playing with bare hand (reference) | Product X | % | Product Y | % | GrindClaw v5 | % |
|---|---|---|---|---|---|---|---|
| **Total score** | **16065.1 ±1449.5** | **17347.3 ±596.3** | **+8.0** | **16922.9 ±1133.9** | **+5.3** | **18406.1 ±1067.1** | **+14.6** |
| AngleShot | 612.4 | 676.6 | +10.5 | 695.5 | +13.6 | 769.4 | +25.6 |
| FourShot | 2337.0 | 2459.6 | +5.2 | 2432.6 | +4.1 | 2547.5 | +9.0 |
| Suavetrack | 2533.9 | 3023.6 | +19.3 | 3052.4 | +20.5 | 3494.8 | +37.9 |
| Blinktrack | 2819.1 | 3134.4 | +11.2 | 2926.8 | +3.8 | 3141.8 | +11.4 |
| Swayswitch | 3642.0 | 3866.6 | +6.2 | 3726.3 | +2.3 | 3999.9 | +9.8 |
| Dodgeswitch | 4120.8 | 4186.4 | +1.6 | 4089.4 | -0.8 | 4452.9 | +8.1 |

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All the tested products have shown higher total score in comparison with data of playing without any wrist support (playing with bare hand). Some tested products showed better results in specific tests (Table 2.1).

The highest results were observed in the **GrindClaw testing** (mean total score 18406.1±1067.1 for GrindClaw vs. 16065.1±1449.5 while playing with a bare hand, i.e., higher by 14.6%; p=0.022). The total score in the initial trial and at the end were quite similar (p>0.05), even slightly higher than initial (mean total score initially 18223.5±860.0 points vs. 18588.8±1352.2 at the end). Analysing by dexterity tests and measurement time separately, the same trend was observed in most tests, except for Dodgeswitch test, where the score at the end was lower than the initial one on that day (see Figure 2.2G). Better improvement in the total score was observed in Suavetrack, AngleShot, and Blinktrack. Probably, this might be explained by specific movements required by certain tests. Overall, GrindClaw prototype provided good gliding and mobility of the wrist, supporting the sufficient performance of the gamer.

The second highest result was revealed in the **Product X testing** (17347.3 ±596.3 points vs. 16065.1±1449.5 while playing with bare hand, i.e., higher by 8.0%; p=0.022). The results at the end of the trial were higher than in initial run on that day – 17158.5±550.5 vs. 17536.0±657.0, p>0.05. Improvement of the result in comparison with playing with a bare hand was discovered mainly in Suavetrack, Blinktrack, and AngleShot tests, where good gliding of the wrist on the desk surface is necessary for successful performance).

Results of Product X and GrindClaw were quite similar to each other with some differences in performing several tests and extent of improvement. It is important to note, that improved gliding of the wrist with computer mouse was observed both in GrindClaw glove and Product X wrist support, but some limited rotation and insufficient side movements of the wrist was identified in Product X tests.

**Product Y testing** presented results lower than in Product X. The total score was higher than in playing with a bare hand (16922.9 ±1133.9 for product Y vs. 16065.1±1449.5 for playing with a bare hand, i.e., higher by 5.3%; p>0.05), but still lower than in Product X and GrindClaw tests. The results of the end trial were almost equal to that in initial (initial 16884.0±674.9 vs. 16961.75±1593.8 at the end; p>0.05). Worsening of the results was even observed in Dodgeswitch test, especially at the end trial. This could be explained by tiredness of participants after 3-hour-long playing (although this effect was not detected in other scenarios) or by effect of the glove on the wrist function while performing specific movements and tasks. On the contrary, the significant improvement was identified in Suavetrack test in comparison playing with a bare hand and in AngleShot test at the end trial in comparison with initial trial. Some limitation in gliding of the wrist and lack of wrist basement support was noticed in Product Y tests.

The lowest total score of 6 standardized tests was found out in **playing with a bare hand** scenario (i.e., without using any product) – mean total score was 16065.1 ±1449.5 points. The low results were found out both in initial trial and at the end (16019.3±1754.7 initially and 16111.0±1348.3 at the end). At the end trial the results slightly improved, but still were lower than in other tested scenarios. This trial was the first for all study participants, and gamers had no experience in this type of test. This fact could influence in some way the results. In most of the scenarios the end trial has shown the increase in the total score, except for Product Y testing.

Some individual differences were observed between tested gamers (see Annexes 1-4), but this effect varied among different dexterity tests. Overall, one gamer (ID4) was slightly better skilled than others, but this did not significantly affect the results of the tests.

Two women and two men participated in the tests, but there was no significant difference in performing the tests from the point of view of genders (p>0.05).

**Figure 2.1. Test results of the fine motor function of the wrist (total score of dexterity tests by tested scenario and test time; AimLab)**

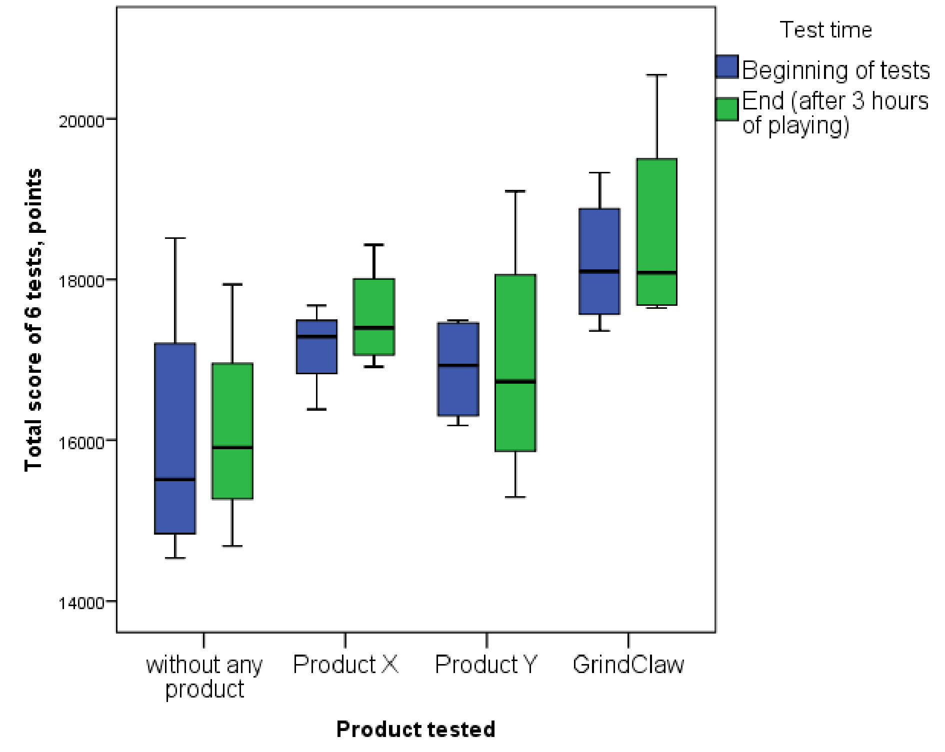
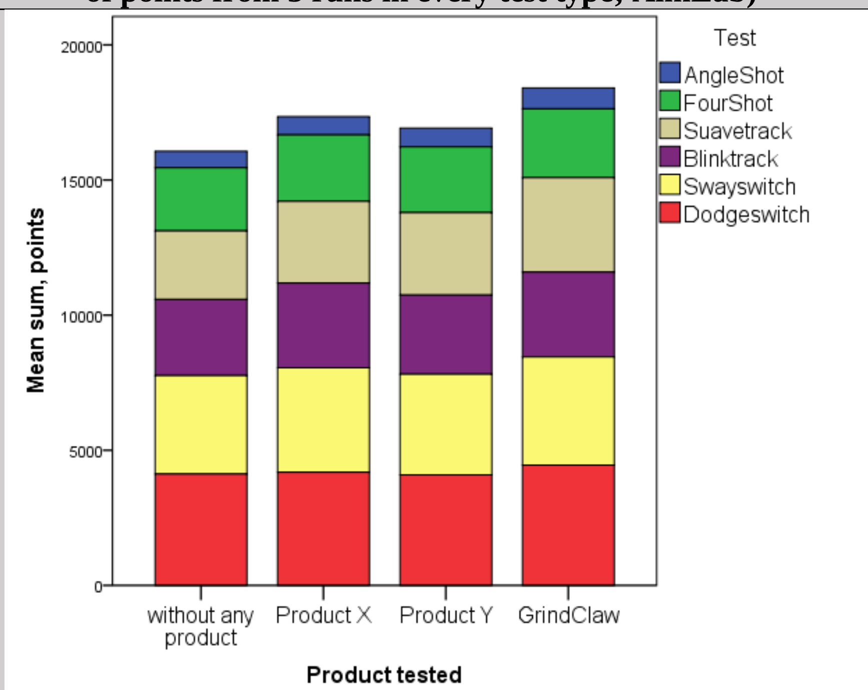
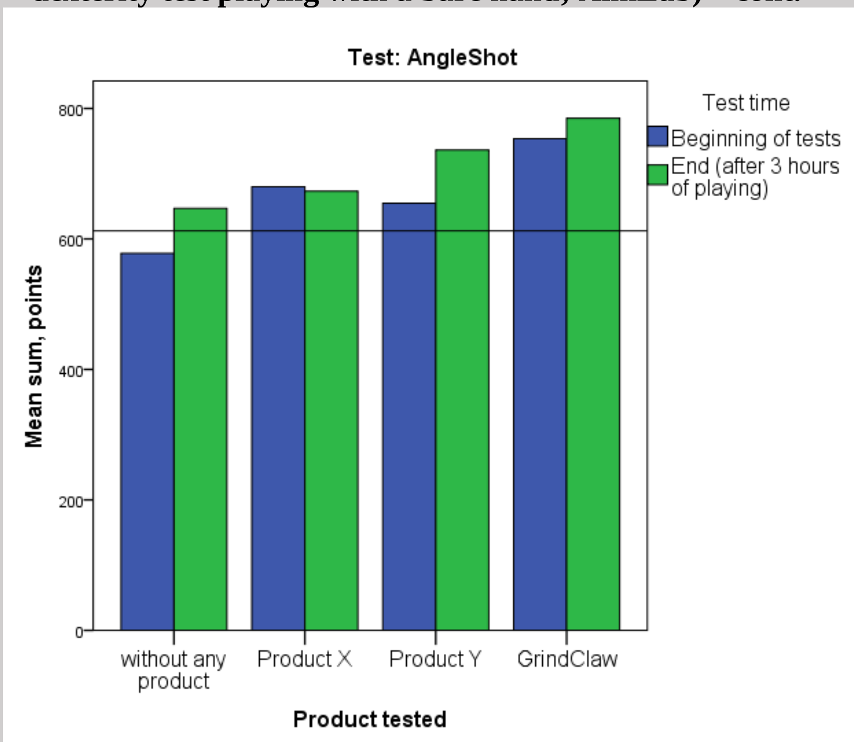



**Figure 2.2. Summary of the fine motor function testing results by tests and tested scenario (mean sum of points from 3 runs in every test type; AimLab)**

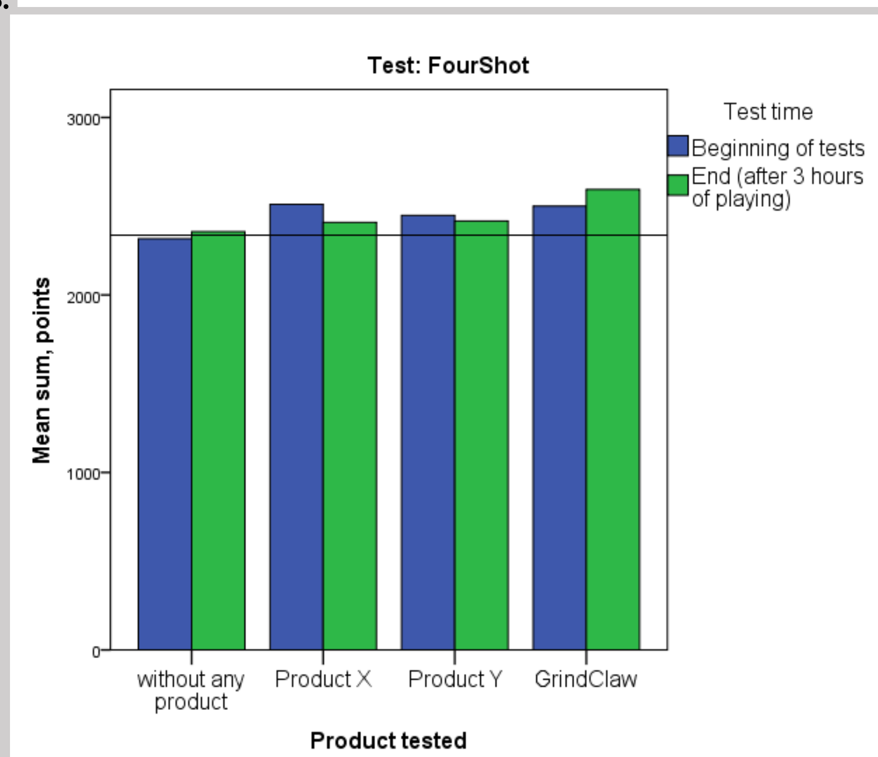



**A.**

**Figure 2.2. Summary of the fine motor function testing results by tests and tested scenario (mean sum of points from 3 runs in every test type; reference line represents mean score in corresponding dexterity test playing with a bare hand; AimLab) – cont.**




**B.**




**C.**

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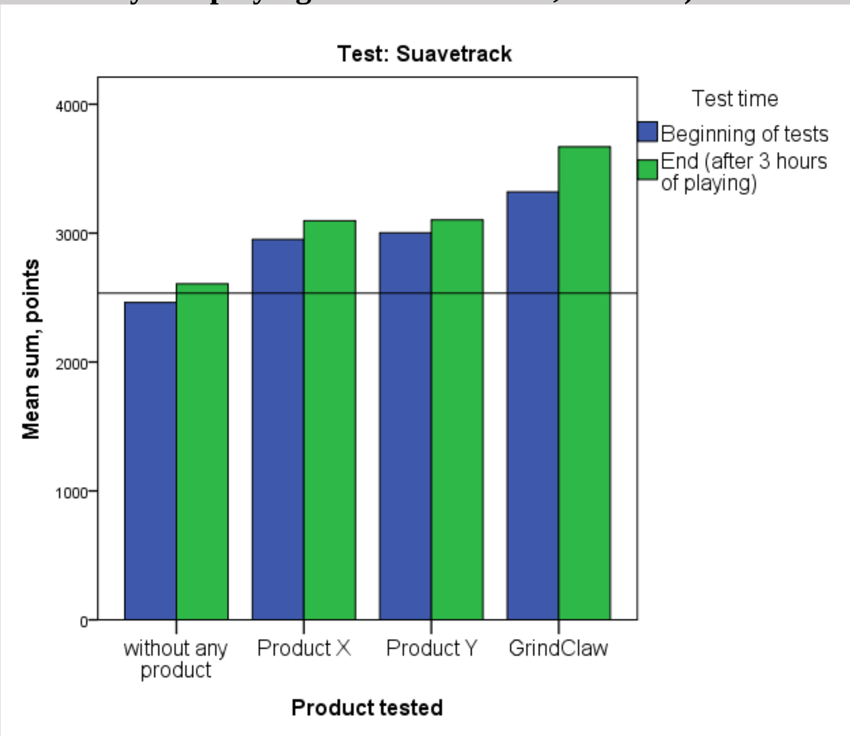


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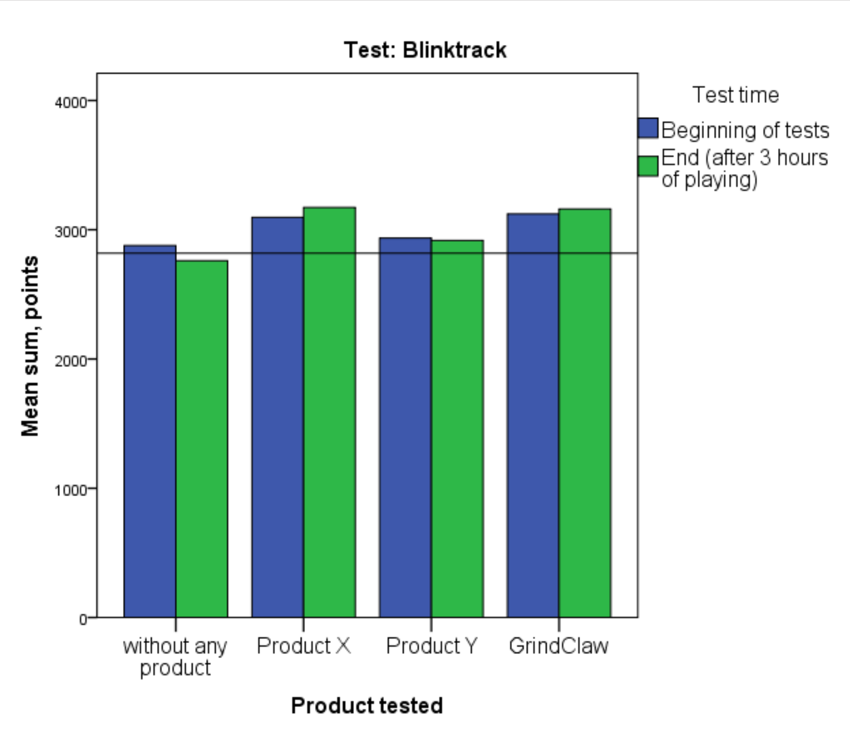
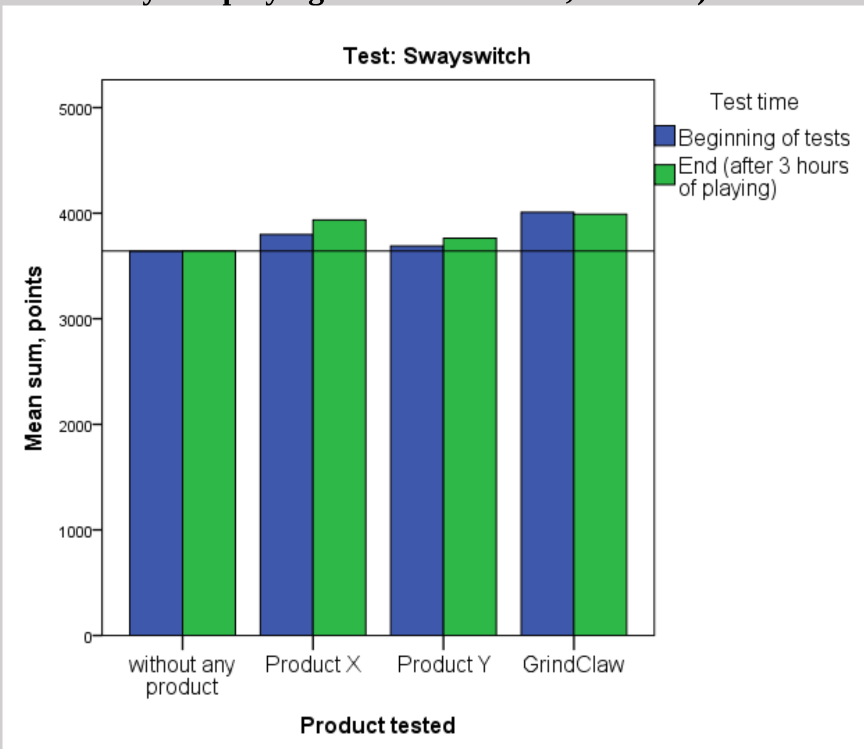
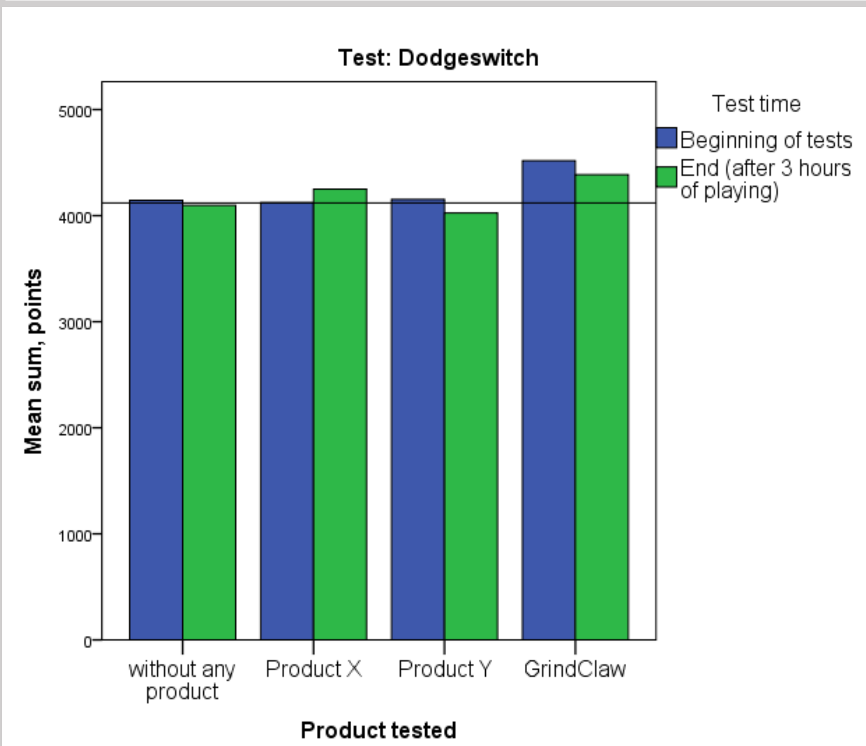



E.

**Figure 2.2. Summary of the fine motor function testing results by tests and tested scenario (mean sum of points from 3 runs in every test type; reference line represents mean score in corresponding dexterity test playing with a bare hand; AimLab) – cont.**




F.




G.

## 2. Results of wrist skin moisture testing

Skin moisture is a dynamic physiological parameter which depends on many factors: hydration state of the person, emotions, mental and physical load, presence of specific diseases and skin health (e.g., fever, skin diseases), pharmaceuticals, environmental conditions (air humidity and temperature, air flow velocity), use of cosmetics, transparency of the clothes for water vapours. Water loss from skin surface differs significantly by body areas, e.g., palm is sweating much more than dorsal surface of the wrist.

Current testing was performed in standardized laboratory environmental conditions to avoid the effect of changing environmental conditions on measurement results. Mean air temperature during all the trials was 22.9 ± 0.6°C and air humidity was 44.1 ± 2.7%, air flow was kept minimal. Study participants were young and healthy individuals without skin problems, who were well hydrated and allowed to drink water of room temperature as much as needed.

In all tested scenarios, significant dynamic fluctuation of transepidermal water loss (TEWL) was observed (Figure 2.3). The highest fluctuation was identified in the palm surface of the wrist (Figure 2.3., blue lines). The palmar surface of the wrist has much more sweat glands, therefore humidity and evaporation there can be significantly higher than in other areas. The dorsal surface of the wrist and wrist basement showed lower TEWL and significantly less fluctuation in comparison with palmar surface. The increase of sweating of palmar surface was noted during more intensive mental and physical load (i.e., dexterity tests at the beginning of the trial and at the end of the 3rd hour). A decrease of skin humidity appeared during the resting periods (15-minutes-long breaks after the 1st and 2nd hour). Taking into account that during the 2nd hour of the trial there was just playing computer games common for these gamers without specific tests and stresses, TEWL at the end of the 2nd hour was less affected by intensive load and was used for detailed analysis across tested scenarios (Figure 2.4 and 2.5).

TEWL parameters by measurement time, site and scenario are summarized in the Table 2.2.

Table 2.2

**Average TEWL during the trial and TEWL at the end of the 2nd hour by tested scenario and measurement site (TEWL, g/m²h ± standard deviation and percent from scenario "playing with a bare hand without any product")**

| Scenario / TEWL measurement site | Without anything (reference) | Product X | | Product Y | | GrindClaw | |
|---|---|---|---|---|---|---|---|
| | mean | mean | % | mean | % | mean | % |
| **Average TEWL during the trial** | | | | | | | |
| Palmar surface | 53.3 ±14.1 | 48.6 ±13.6 | -8.8 | 56.5 ±15.0 | +6.0 | 59.2 ±16.9 | +11.1 |
| Wrist basement | 20.9 ±9.4 | 17.4 ±7.6 | -16.7 | 15.3 ±6.9 | -26.8 | 14.4 ±7.9 | -31.1 |
| Dorsal surface | 17.8 ±4.4 | 16.5 ±4.9 | -7.3 | 16.4 ±3.6 | -7.9 | 14.6 ±3.9 | -18.0 |
| **TEWL at the end of the 2nd hour** | | | | | | | |
| Palmar surface | 55.9 ±5.7 | 50.6 ±9.2 | -9.5 | 55.7 ±10.0 | -0.4 | 62.1 ±8.0 | +11.1 |
| Wrist basement | 19.0 ±9.8 | 18.1 ±11.0 | -4.7 | 13.3 ±2.0 | -30.0 | 12.4 ±3.2 | -34.7 |
| Dorsal surface | 17.5 ±2.9 | 15.7 ±4.6 | -10.3 | 14.6 ±5.4 | -16.6 | 15.7 ±3.0 | -10.3 |

**The dorsal surface of the wrist** showed least fluctuations of skin humidity during the tests (Figure 2.3, yellow line). The lowest fluctuations were observed in the GrindClaw testing. TEWL after the 2$^{nd}$ hour from the dorsal surface of the wrist was very similar in Product X, Product Y and GrindClaw tests (Figure 2.4, green columns). It should be noted that Product X has no large cover for the wrist dorsum. It means that Product Y and GrindClaw (which are gloves) has breathable material and do not affect significantly the humidity of the dorsal surface of the wrist. At the same time skin humidity of the wrist dorsal surface in playing with a bare hand was slightly higher than in all tested products.

TEWL of the **wrist basement** was highest in playing with a bare hand (Figure 2.4, blue columns). The second highest result was observed in the Product X testing. Scenarios showed also quite high dynamic fluctuation of parameters. This could be explained by close contact of the skin with computer mouse, desk surface and Product X surface. This does not allow sweats to evaporate sufficiently, while intensive evaporation persisted during the breaks. Significantly lower TEWL was detected in tests of gloves. The lowest TEWL of the wrist basement was identified in GrindClaw testing. The second lowest parameter, which is very close to the GrindClaw parameters, was TEWL in Product Y. These scenarios presented also lower fluctuations of TEWL parameters (Figure 2.3, red line).

TEWL of the **wrist palmar surface** showed the highest dynamic fluctuations because of intensive sweating and changing the load. Maximal TEWL was observed after the 1$^{st}$ hour in all trials. Probably, in the beginning of the trial study participants experienced intensive stress because of the dexterity tests that stimulated extensive sweating of the palm. The highest TEWL after the 1$^{st}$ hour was observed in GrindClaw testing and the lowest one was identified in Product X (Figure 2.5).

Comparing TEWL of palm after the 2$^{nd}$ hour of testing it was revealed, that the lowest (even lower than in playing with a bare hand) one was in the Product X testing, but the highest one appeared in GrindClaw scenario. This could be explained with construction of Product X wrist support which provides better ventilation of palmar skin keeping it more away from the surface of the computer mouse, while GrindClaw glove has additional perforated leather element on the palmar surface which limits evaporation. TEWL of the palm in testing of Product Y and playing with a bare hand were very similar.

Slight individual variations of TEWL dynamics across tested scenarios were observed among study participants (see Annexes 1-4).

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.3. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist and tested scenario (mean TEWL, g/(m$^2$h)**

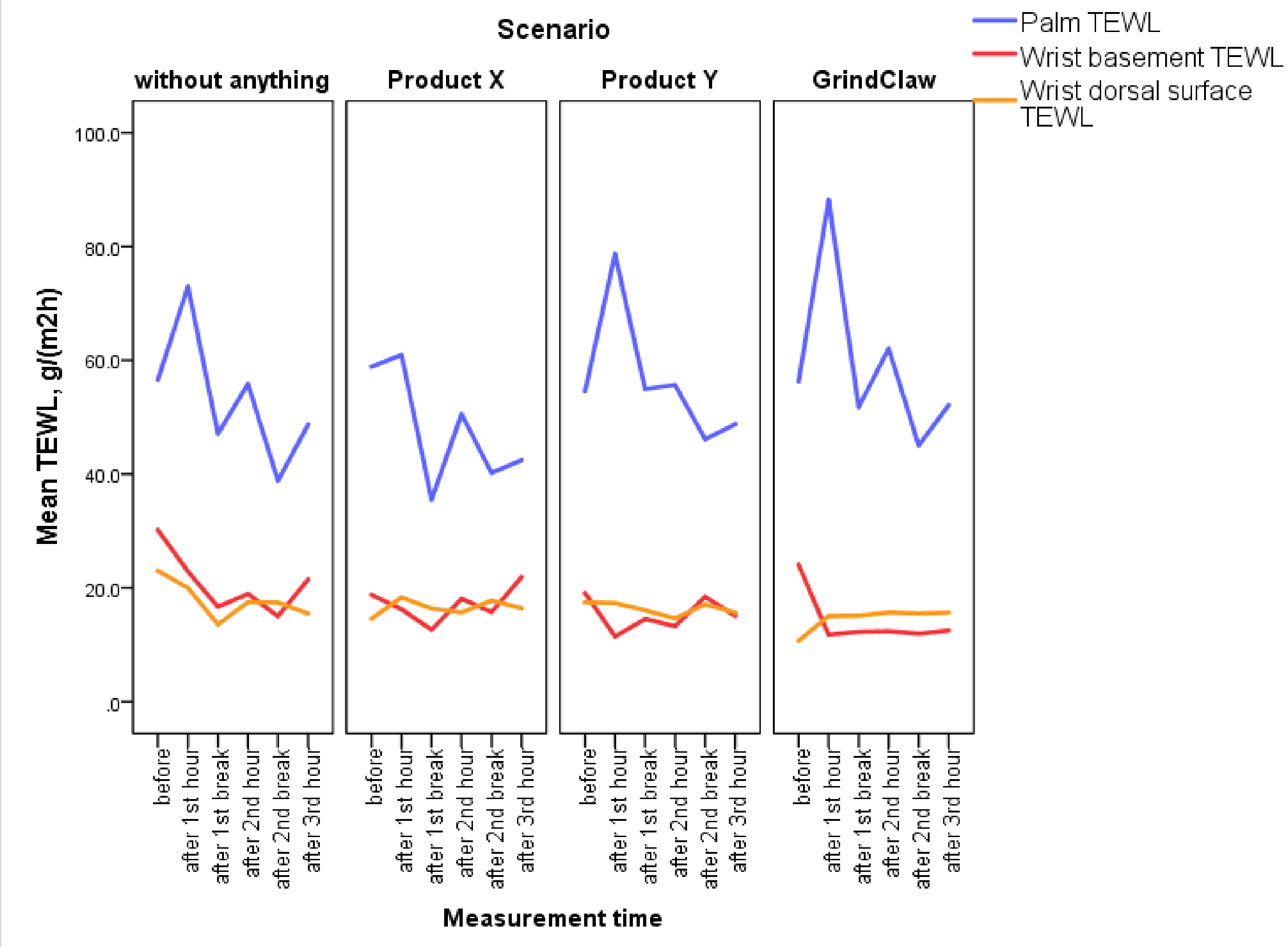
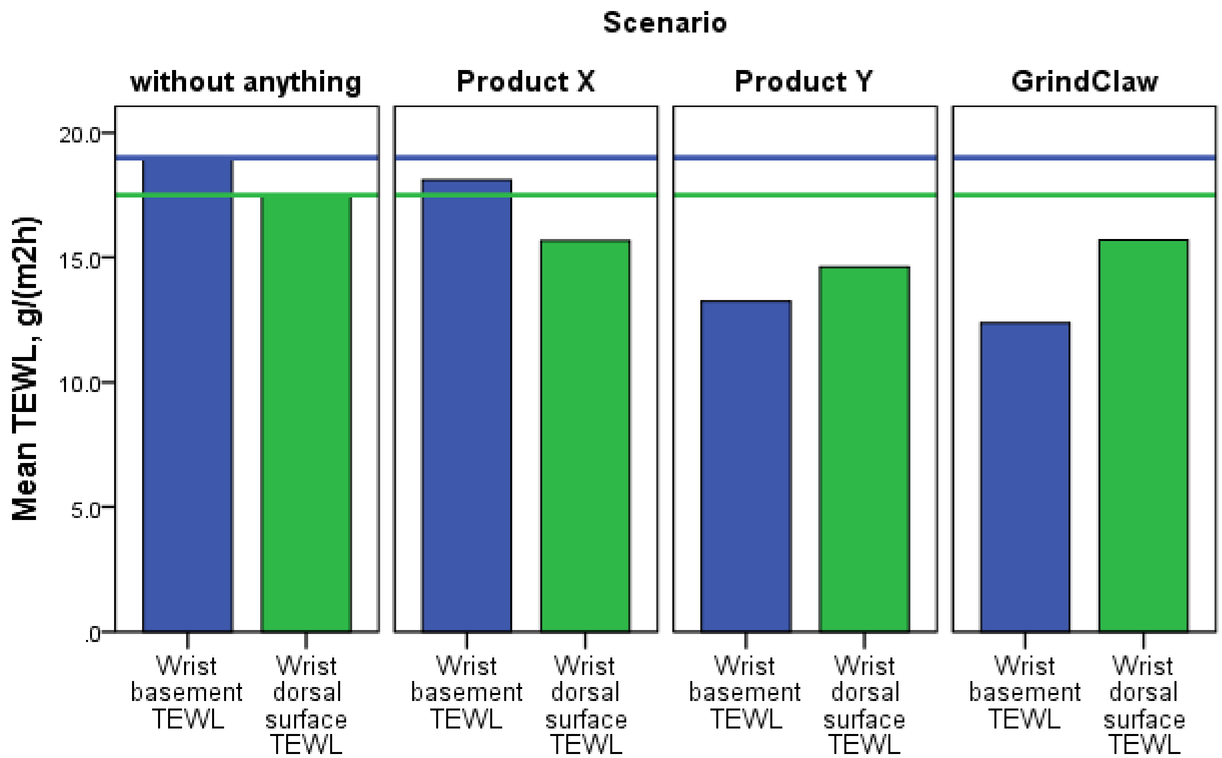


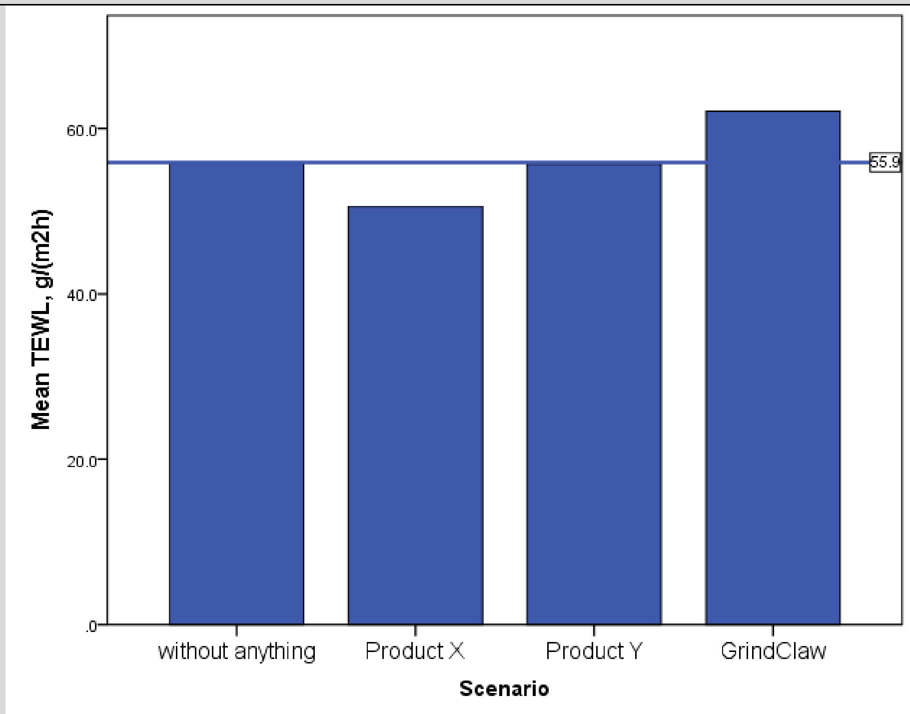
**Figure 2.4. Summary of skin moisture measurements in the right wrist after the 2nd hour of continuous playing (mean TEWL, g/($m^2$h) by measurement site (wrist basement and dorsal surface) and tested product)***




*Reference lines represent the mean TEWL at the end of the 2nd hour for playing with a bare hand (without any product; blue line for the wrist basement, green – for wrist dorsal surface).

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.5. Skin moisture measurements of the right wrist palmar surface after the 2nd hour of continuous playing (mean TEWL, $g/(m^2h)$ by tested product)***




*Reference line represents the mean TEWL from the palmar surface of the right wrist at the end of the 2nd hour for playing without any product.

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## 3. Results of soft tissue compression and microcirculation testing by infrared thermography

Digital infrared thermography is a method where the heat coming from objects is registered by highly sensitive infrared camera, and map of surface temperature is produced. Heat amount emitted by human body depends on many physiological processes and environmental factors: tissue blood supply, physical activity level, thickness of subcutaneous fat layer and nutritional status, endocrine fluctuations, presence of inflammatory process, ambient temperature, air humidity, air flow, thickness of clothes, etc. When a person is physically active, muscles produce more heat, and intensively working superficially located muscles can be visualised by medical infrared thermography as areas with increased surface temperature. On the contrary, in case of sedentary behaviour when muscles produce less heat, body tries to keep it closer to vitally important organs and reduces blood flow to peripheral parts. This process causes reduction of temperature in periphery of extremities. Besides of that, friction of skin and superficially located tissues during work activities or movements causes increase of blood flow and subsequently increase in surface temperature. Compression of body tissue causes reduction of blood supply and decrease of temperature in supplied body parts. But after the release of the pressure (e.g., removing glove from the hand) blood supply locally is restored and previously compressed areas can be well seen with increased surface temperature. All this can be visualised and assessed by infrared thermography.

Knowing that this method is highly sensitive to ambient factors, all the measurements in the current study were performed in laboratory settings under controlled environmental conditions. Mean air temperature during the tests was 22.9 ± 0.6°C, air relative humidity was 44.1 ± 2.7%, and air flow was kept minimal. These conditions did not differ significantly across the test days and scenarios. All study participants were healthy individuals with normal body mass index (mean body mass index was 21.2±1.0 kg/$m^2$), that allowed clearly visualise tested muscle and soft tissue thermal effects.

Due to prolonged sitting and sedentary behaviour during the 3-hour-long gaming with only 15 minutes breaks after every hour, decrease in the wrist temperature in all test participants and all tested products was observed, starting from the second hour contrary to the constant room temperature (Figures 2.6-2.12). At the same time, slight increase of skin temperature above the forearm muscles was observed after intensive and prolonged gaming periods because of intensive load for forearm muscles (Figures 2.6-2.9 and Figure 2.12).

Insignificant individual variations in parameters were observed during the first hour and at the end of the 3$^{rd}$ hour, but during the whole 2$^{nd}$ hour and first half of the 3$^{rd}$ hour stable low temperature of fingers was detected (see Annexes 1-4 Figures 3.1-3.3.). Regular breaks in gaming did not affect significantly finger temperature. In the Product Y tests slightly higher temperature of fingers of some study participants persisted for a longer periods. This could be explained by thicker fabric used in Product Y construction that kept wrist heat for a longer time. In GrindClaw tests initially higher temperature remained in some participants during the first hour.

Moderate statistically significant negative correlation was observed between the 4$^{th}$ finger mean temperature and time in playing with a bare hand (Spearman's correlation coefficient $r_s$ was -0.592, p<0.001) and slightly weaker correlation in using Product X ($r_s$ = -0.515, p<0.001). Weak negative correlation was found out in using Product Y ($r_s$ = -0.366, p=0.004) and the weakest correlation among tested scenarios was found out in GrindClaw tests ($r_s$ = -0.301, p=0.019). Negative correlation means that temperature dropped with time. Larger absolute value of correlation coefficient could be interpreted as the closer connection between temperature drop and time, i.e., sharper decrease of skin temperature in scenarios, where playing with a bare hand and using Product X was performed. For GrindClaw, weaker correlation could be interpreted by larger fluctuations in skin temperature over time, e.g., short-term increase of 4$^{th}$ finger temperature initially was observed 15-30 minutes after the start of GrindClaw tests and then temperature sharply decreased till the end of the 1st hour while preserving this low temperature till the 3rd hour and sharply increasing at the second half of the 3rd hour. In playing with a bare hand and in Product X tests such notable fluctuations were not observed: there was just sharp decrease and remaining stable low temperature. In Product Y tests significant fluctuations also were observed. Higher skin temperature and fluctuations in such cases could be explained with better blood circulation and preserving heat in the wrist for a longer time. It is important to note that GrindClaw and Product Y are gloves which cover largest part of the wrist preserving some heat under the fabric and affecting heat exchange differently from that in playing with a bare hand and wrist support like Product X.

Similar correlations were observed also between mean temperature of the 5th finger and time, as well as between minimal temperature in the 5th finger and time.

On the contrary, such correlation was not found out for skin temperature over forearm proximal lateral surface. Very weak statistically insignificant correlation was identified between skin temperature over forearm and time in Product X tests ($r_s$ = 0.125, p=0.341) and in playing with a bare hand ($r_s$ = 0.116, p=0.379). For GrindClaw and Product Y tests correlation was even lower ($r_s$ = 0.065, p=0.621 for GrindClaw and $r_s$ = 0.040, p=0.762 for Product Y). Larger absolute value of correlation coefficient here means the larger connection of skin temperature with time (Figure 2.12) and larger load for wrist extensor muscles, related to intensive playing periods.

Analysing mean temperature by interest zones, minor differences were found out in comparison between scenarios (Table 2.3). Mean temperature of fingers in playing with a bare hand and Product X scenario was very similar and did not differ significantly (e.g., mean temperature of 4th finger was 18.5±2.5 ºC for playing with a bare hand vs. 18.5±2.3 ºC for using Product X; p>0.05). This indicates similar microcirculatory conditions for the wrist in both scenarios.

Slightly higher mean temperature of the 4th finger was in Product Y and GrindClaw tests: 19.2±3.3 ºC for Product Y and 18.6±3.4 ºC for GrindClaw. These both products are glove that can keep heat of the body for a slightly longer time. Material of Product Y was more dense and thicker, so it kept slightly higher temperature of fingers than GrindClaw. Similar differences were observed in the 5th finger as well.

On the contrary, in the forearm mean temperature the highest values were observed in playing with a bare hand (26.1±0.9 ºC), indicating higher load for extensor muscles while playing without any specific wrist support. For other scenarios forearm mean temperature values were very similar to each other, but lower than in a bare hand playing: 25.9±1.0 for Product X, 25.8±0.73 for GrindClaw, and 25.7±1.2 ºC for Product Y.

In analysis of soft tissue compression in the wrist regarding the tested products, playing with a bare hand was used as the reference. In playing with bare hand no significant compression sites were observed in the wrist. After the use of Product X, most significant compression sites were noticed on the palmar surface at the basement of the wrist, but not on the dorsal surface where fixing strap was located (Figure 2.13, compression sites are shown by red arrows). Product Y caused some compression of soft tissues on the side and dorsal surfaces of the wrists symmetrically in right and left arm but did not cause significant compression of palmar surface. These compression sites correspond to location of seams and fastener in the gloves (Figure 2.14). The GrindClaw use did not cause significant changes at the palmar surface, only some sites of compression were noticed along the seams on the dorsolateral surface of the wrist, radial surface of the wrist basement, and on the ulnar surface at the basement of the 3rd finger (Figure 2.15).

Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY
AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

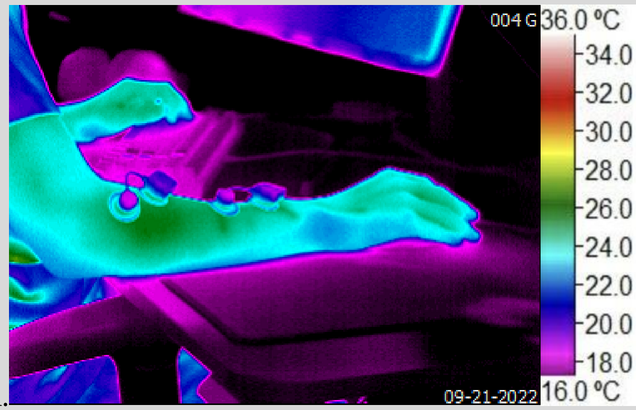
Table 2.3

**Thermographically assessed mean temperature and difference from playing with a bare hand by interest zones and tested scenarios (°C, %)**

| Scenario tested | Interest zone | Mean temperature, °C | Standard deviation | Difference, °C | Difference, % |
|---|---|---|---|---|---|
| **Without anything (reference)** | 4th finger mean temperature | 18.52 | 2.51 | - | - |
| | 5th finger mean temperature | 18.53 | 2.20 | - | - |
| | 5th finger minimal temperature | 17.90 | 2.33 | - | - |
| | Forearm mean temperature | 26.08 | 0.90 | - | - |
| **Product X** | 4th finger mean temperature | 18.52 | 2.28 | 0.00 | 0.0 |
| | 5th finger mean temperature | 18.48 | 1.97 | -0.05 | -0.2 |
| | 5th finger minimal temperature | 17.97 | 2.00 | 0.07 | 0.4 |
| | Forearm mean temperature | 25.85 | 0.99 | -0.23 | -0.9 |
| **Product Y** | 4th finger mean temperature | 19.23 | 3.33 | 0.71 | 3.8 |
| | 5th finger mean temperature | 19.19 | 2.98 | 0.66 | 3.6 |
| | 5th finger minimal temperature | 18.87 | 3.03 | 0.97 | 5.4 |
| | Forearm mean temperature | 25.72 | 1.19 | -0.36 | -1.4 |
| **GrinClaw** | 4th finger mean temperature | 18.64 | 3.35 | 0.12 | 0.6 |
| | 5th finger mean temperature | 18.78 | 3.06 | 0.25 | 1.4 |
| | 5th finger minimal temperature | 18.24 | 3.14 | 0.35 | 1.9 |
| | Forearm mean temperature | 25.84 | 0.73 | -0.25 | -1.0 |

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.6. Infrared digital thermal images indicating lower arm skin temperature changes while gaming for 3 hours with a <u>bare hand</u> (without any product; reference) in standard environmental conditions (A. at the beginning of the test; B. after 3 hours of gaming; colour scale on the right side shows corresponding temperature, °C)**

A.


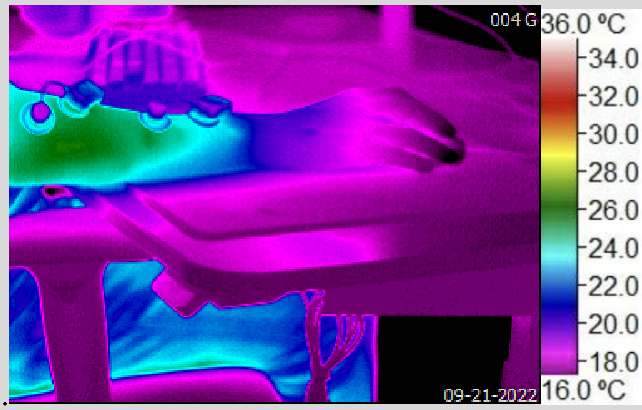
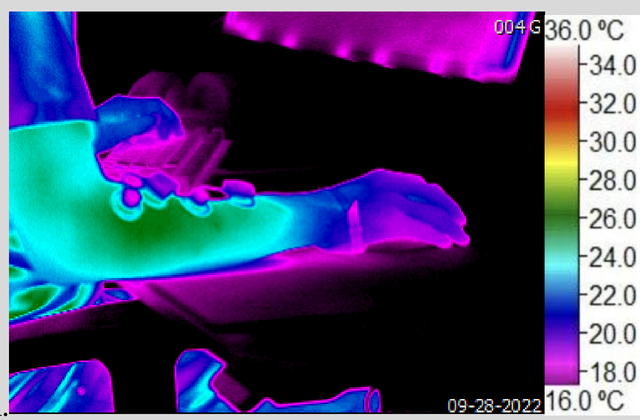

B.



**Figure 2.7. Infrared digital thermal images indicating lower arm skin temperature changes in the process of gaming for 3 hours and using <u>Product X</u> in standard environmental conditions (A. at the beginning of the test; B. after 3 hours of gaming; colour scale on the right side shows corresponding temperature, °C)**

A.


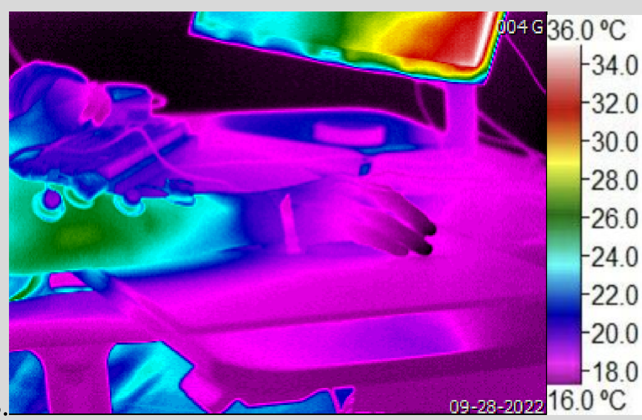
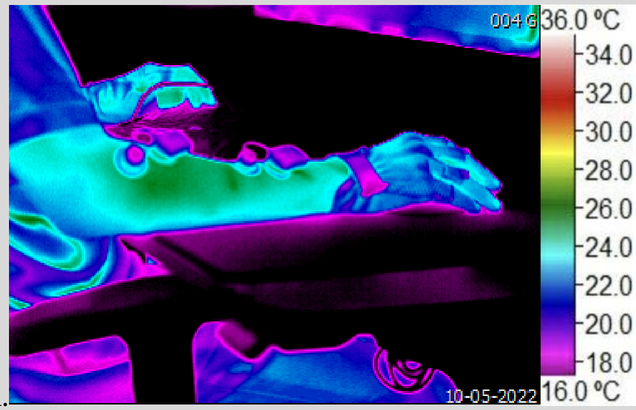

B.


**Figure 2.8. Infrared digital thermal images indicating lower arm skin temperature changes in the process of gaming for 3 hours and using <u>Product Y</u> in standard environmental conditions (A. at the beginning of the test; B. after 3 hours of gaming; colour scale on the right side shows corresponding temperature, °C)**

A. 

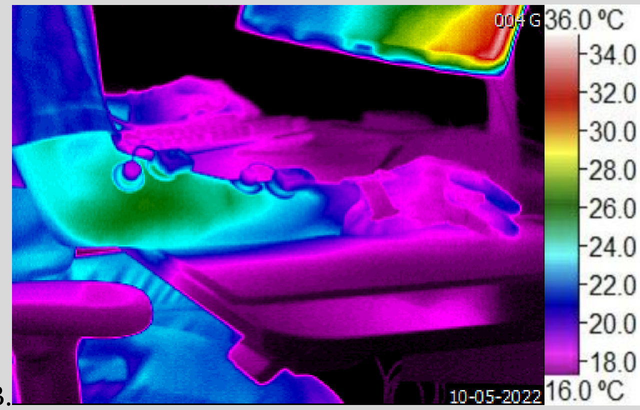
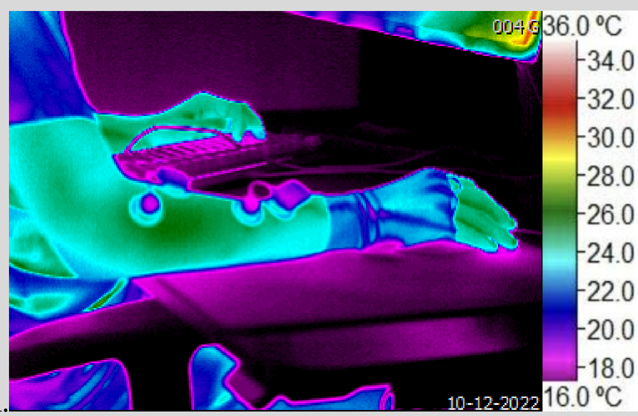
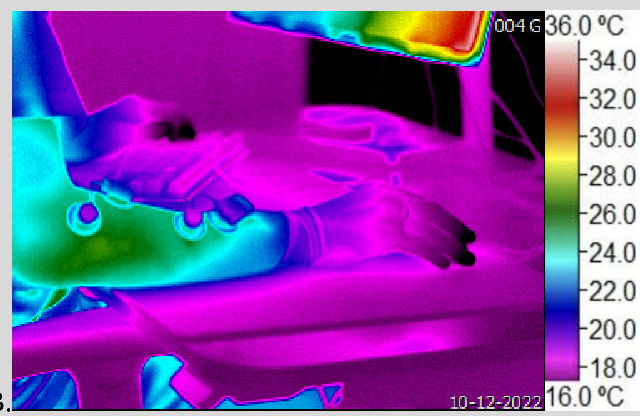

B. 


**Figure 2.9. Infrared digital thermal images indicating lower arm skin temperature changes in the process of gaming for 3 hours and using <u>GrindClaw</u> in standard environmental conditions (A. at the beginning of the test; B. after 3 hours of gaming; colour scale on the right side shows corresponding temperature, °C)**

A. 


B. 

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.10. The dynamics of mean skin surface temperature of the right wrist 4th finger by measurement time and tested scenario (°C)**

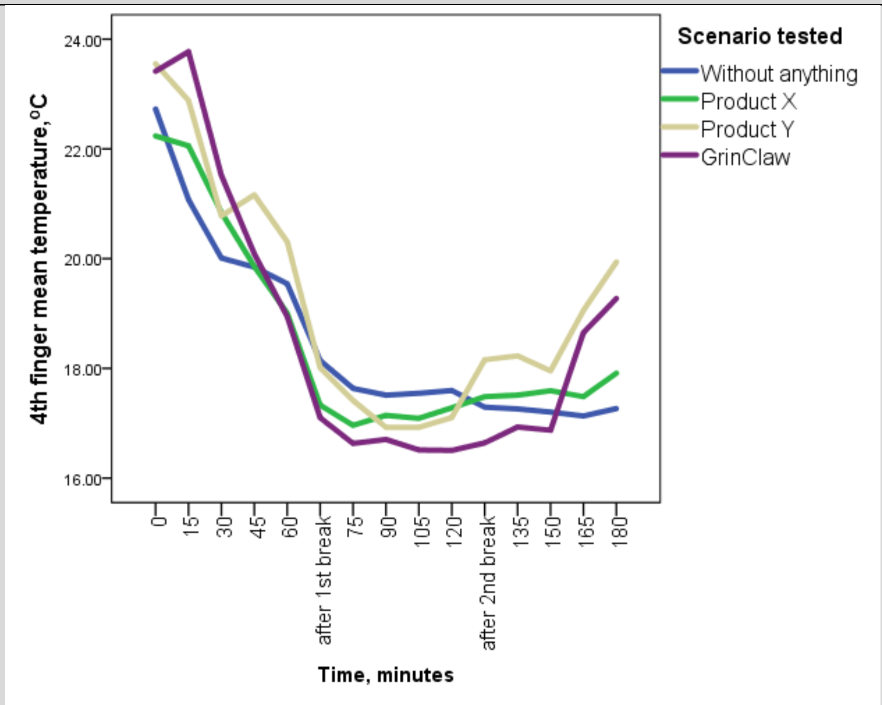
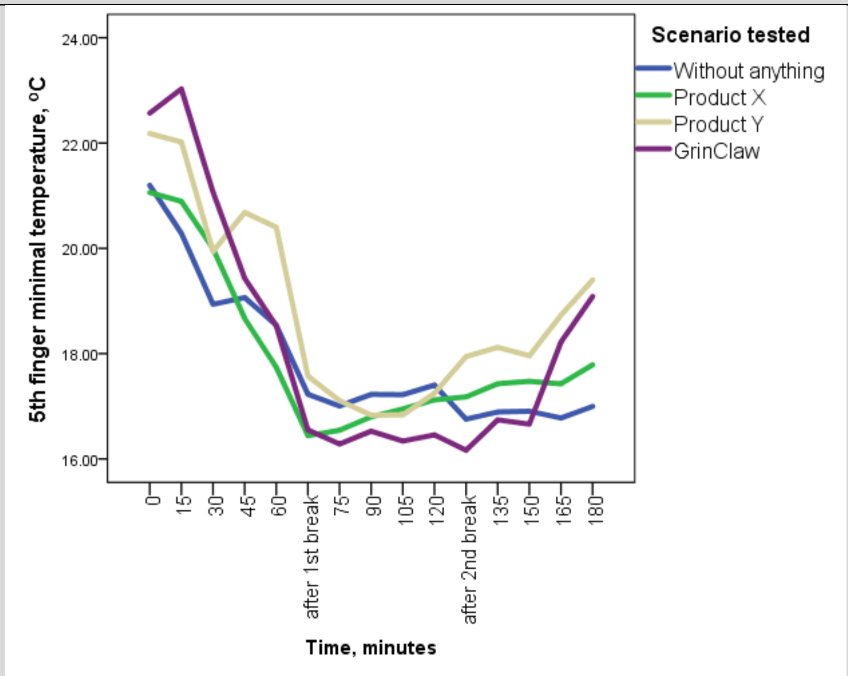


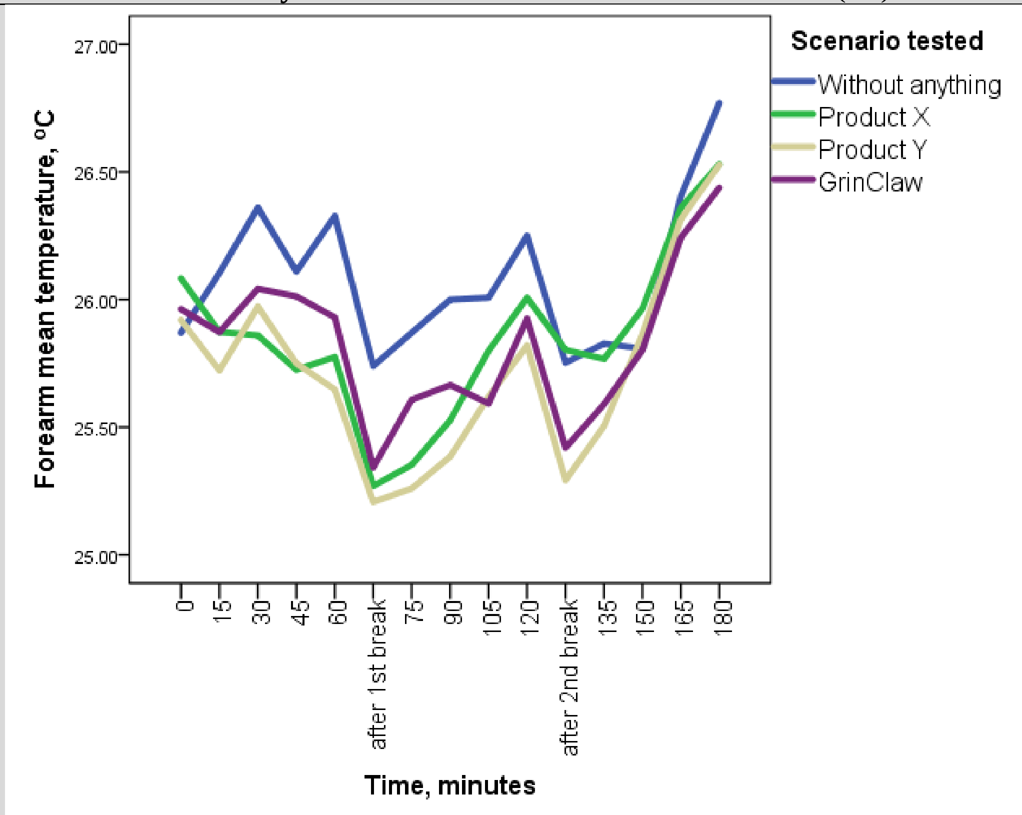

**Figure 2.11. The dynamics of minimal skin surface temperature in the right wrist 5th finger by measurement time and tested scenario (°C)**



RĪGAS STRADIŅA UNIVERSITĀTE

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.12. The dynamics of mean skin surface temperature in the lateral proximal part of the forearm by measurement time and tested scenario (°C)**



Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.13. Photographs (A, B) and infrared images (C-F) illustrating compression sites on the palmar surface of the wrist basement after use of <u>Product X wrist support</u> (arrows indicate compression sites)***

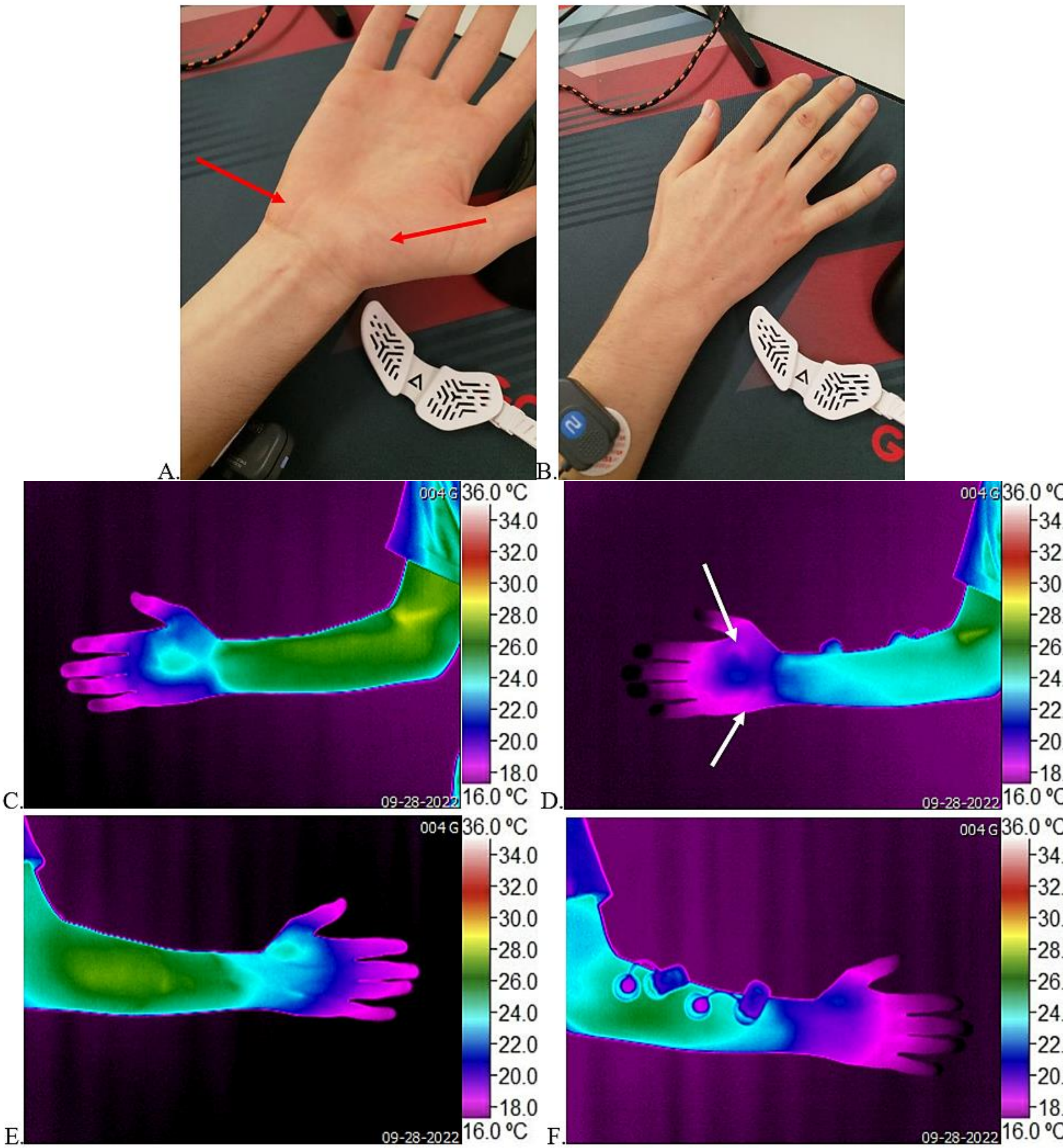



*Figure 2.13.C shows infrared image of <u>palmar surface</u> of the right wrist before testing, D – after testing; E shows infrared image of <u>dorsal surface</u> of the right wrist before testing, F – after testing.

Rīgas Stradiņa Universitāte

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.14. Photographs (A, B) and infrared images (C-F) illustrating compression sites on the palmar surface of the wrist basement after use of Product Y gloves (red arrows indicate compression sites)***


*Figure 2.14.C shows infrared image of <u>palmar surface</u> of the right wrist before testing, D – after testing; E shows infrared image of <u>dorsal surface</u> of the right wrist before testing, F – after testing.

**Figure 2.15. Photographs (A, B) and infrared images (C-F) illustrating compression sites on the palmar surface of the wrist basement after use of GrindClaw v5 prototype glove (red arrows indicate compression sites)***

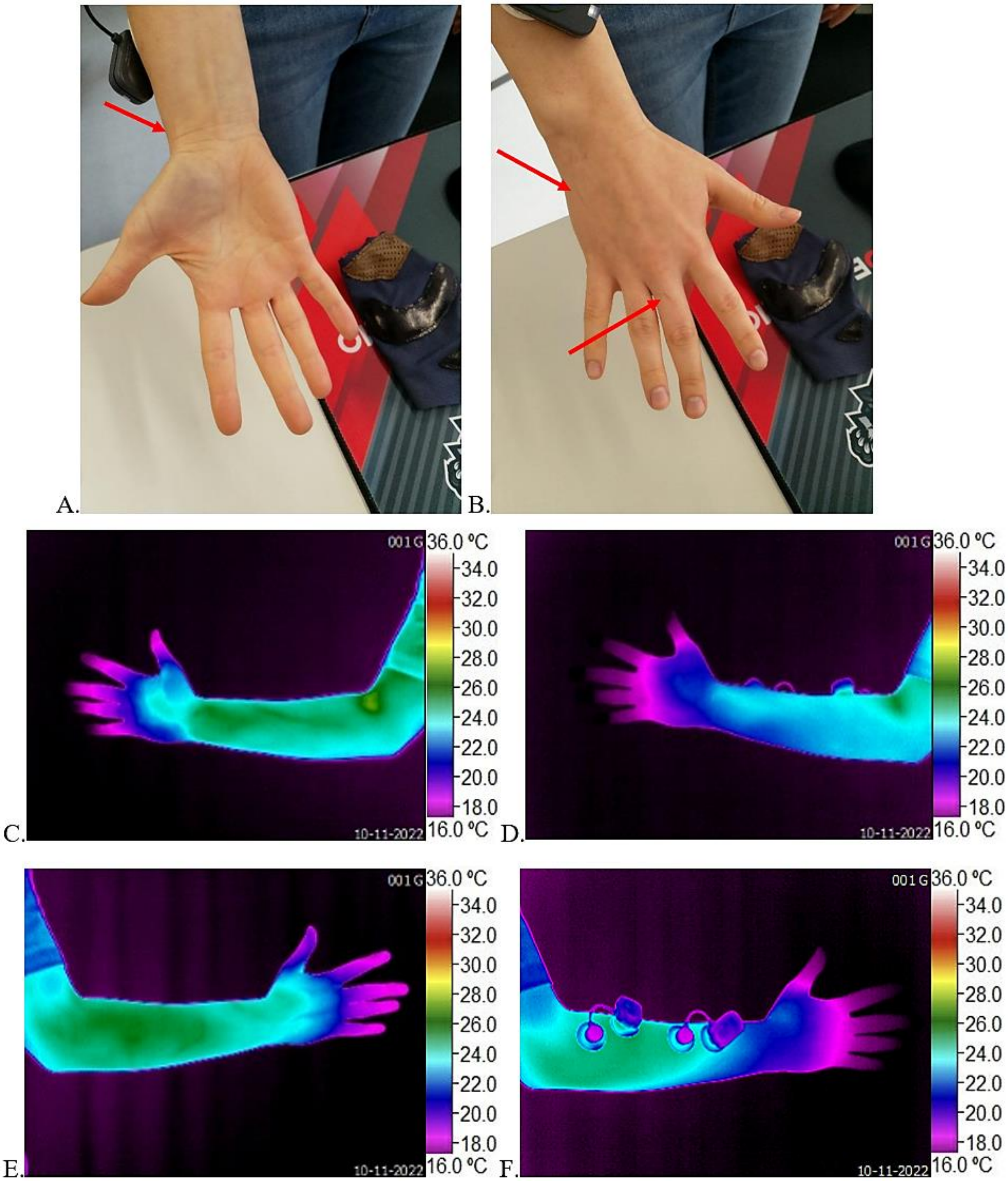



*Figure 2.15.C shows infrared image of <u>palmar surface</u> of the right wrist before testing, D – after testing; E shows infrared image of <u>dorsal surface</u> of the right wrist before testing, F – after testing.

# 4. Results of the surface electromyography in wrist extensor muscles

Surface electromyography (sEMG) is a measurement of electric activity in skeletal muscles which is registered on the surface of the skin. This method provides an opportunity to objectively assess the extent of muscle contraction (i.e., tension and work produced in muscles). The higher the load applied to the muscle the higher voltage is registered on the surface of the skin above the corresponding muscle. The voltage of muscle electric activity depends on size and fitness degree of the muscle, tiredness, skin condition (e.g., greasy or hairy skin produce worse signal from muscles), emotional stress, hydration status, health of the person and many other factors. For this reason, skin surface was carefully prepared before the attachment of electrodes. Study participants were healthy individuals who were specially instructed about the course of the measurements. Knowing that every individual has very different parameters of every muscle, it is extremely complicated to compare one person to another by voltage measurements. To make this comparison possible, maximal electric activity was registered in every study participant before and after every tested scenario. This parameter is very individual. Then actual measurement data from the trials were recalculated to percent from maximal electric activity in corresponding muscle. It is possible to compare these percentages between individuals for detailed analysis. To avoid emotional and conscious effects on sEMG results, study participants were not informed on the exact time of recording. All these precautions ensure that the measurement results are not influenced intentionally and objectively reflect the tested scenario.

The analysis of sEMG measurement results has shown statistically significant differences between tested scenarios ($p<0.05$; Figure 2.16, Table 2.4). The largest differences between scenarios were observed in **extensor carpi radialis longus muscle** (ECRL; $p<0.001$). Extensor carpi radialis longus muscle is mainly responsible for the position of the wrist in relation to the surface (i.e., desk or computer mouse) and extension of the wrist. The electric activity in this muscle reflects quite well how close to the neutral position the wrist is. The highest load for this muscle in right hand was found out in playing with a bare hand without any additional wrist support except horizontal computer mouse itself (Figure 2.16, blue columns).

All the ergonomic products for gamers tested in the current study have shown lower load for ECRL in comparison with playing with a bare hand (Table 2.4). Overall, the Product X and Product Y testing has revealed quite similar electric activity, slightly lower than in playing with a bare hand (9.35±3.17 for Product X and 9.46±2.49 for Product Y vs. 10.13±4.78 in playing with a bare hand; $p>0.05$). The lowest muscle load among all current tests was observed in the GrindClaw testing, and this difference was statistically significant (7.55±1.32 for GrindClaw vs. 10.13±4.78 in playing with bare hand, i.e., by 25.5% lower; $p<0.001$).

**Extensor digitorum** (ED) muscle provides extension and active movements of the fingers. So, the electric activity in this muscle is highly dependent on movements of fingers during the tests, but still the angle at the wrist basement is an important factor for tension in the muscle. The closer the muscle is to the neutral position the lower load is. The highest load in ED muscle was revealed playing with a bare hand (14.47±3.20). All the other tested products have shown slightly lower mean electric activity. The lowest one was observed in the Product Y glove testing (13.20±3.64, i.e., by 8.8% lower than in playing with a bare hand; $p<0.05$). Product X and GrindClaw testing have shown quite similar results (13.73±3.27 for product X and 13.57±3.94 for GrindClaw vs. 14.47±3.20 for playing with a bare hand), but for GrindClaw the difference by -6.2% was statistically significant ($p=0.034$).

At the same time, it is important to note that some differences were identified in the results regarding genders, testing time and manual dexterity tests (Figure 2.17).

Table 2.4

**Summary of surface electromyography measurements by muscles, gender, time, and tested scenario (mean electric activity ± standard deviation, absolute value of difference and percent of change from the value in playing with a bare hand)**

| Scenario | Playing with bare hand (reference) Mean | Product X | | | Product Y | | | GrindClaw v5 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Abs. dif | % | Mean | Abs. dif | % | Mean | Abs. dif | % |
| **Right extensor carpi radialis longus (ECRL)** | | | | | | | | | | |
| **Average in all tests** | **10.13 ±4.78** | **9.35 ±3.17** | **-0.78** | **-7.7** | **9.46 ±2.49** | **-0.67** | **-6.6** | **7.55 ±1.32** | **-2.58** | **-25.5** |
| In the beginning | 10.27 ±4.90 | 9.33 ±3.50 | -0.94 | **-9.2** | 9.59 ±2.42 | -0.68 | **-6.6** | 7.71 ±1.27 | -2.56 | **-24.9** |
| At the end | 9.99 ±4.77 | 9.37 ±2.87 | -0.62 | **-6.2** | 9.34 ±2.60 | -0.65 | **-6.5** | 7.39 ±1.38 | -2.60 | **-26.0** |
| Males | 6.27 ±1.98 | 6.54 ±1.28 | +0.27 | **+4.3** | 7.81 ±1.20 | +1.54 | **+24.6** | 7.27 ±1.23 | +1.00 | **+15.9** |
| Females | 13.99 ±3.43 | 12.16 ±1.55 | -1.83 | **-13.1** | 11.12 ±2.35 | -2.87 | **-20.5** | 7.84 ±1.38 | -6.15 | **-44.0** |
| **Right extensor digitorum muscle (ED)** | | | | | | | | | | |
| **Average in all tests** | **14.47 ±3.20** | **13.73 ±3.27** | **-0.74** | **-5.1** | **13.20 ±3.64** | **-1.27** | **-8.8** | **13.57 ±3.94** | **-0.90** | **-6.2** |
| In the beginning | 14.2 ±2.84 | 13.18 ±3.49 | -1.02 | **-7.2** | 12.68 ±3.69 | -1.52 | **-10.7** | 13.71 ±3.79 | -0.49 | **-3.5** |
| At the end | 14.75 ±3.57 | 14.29 ±3.00 | -0.46 | **-3.1** | 13.72 ±3.58 | -1.03 | **-7.0** | 13.43 ±4.16 | -1.32 | **-8.9** |
| Males | 13.85 ±3.07 | 13.76 ±3.02 | -0.09 | **-0.6** | 11.41 ±2.05 | -2.44 | **-17.6** | 11.11 ±2.84 | -2.74 | **-19.8** |
| Females | 15.09 ±3.28 | 13.71 ±3.57 | -1.38 | **-9.1** | 15.00 ±4.02 | -0.09 | **-0.6** | 16.03 ±3.33 | +0.94 | **+6.2** |

Significant differences in the mean electric activity percent from maximal possible in a muscle were observed between males and females ($p<0.05$; Figure 2.17). This was found out both in ECRL and ED muscles. The difference was especially high in ECRL muscle. The mean percentage from maximal possible electric activity in females was significantly higher than in males in all tested scenarios for both muscles ECRL and ED ($p<0.001$). This could be explained with differences in size and force of muscles in males and females. Males usually have bigger and stronger muscles, for this reason voltage in maximal force test is higher than in females (Figure 2.18). But, recalculating actual electric activity data from trials to the percentage from the maximal muscle electric activity, the portion of force applied for moving computer mouse in males is relatively lower, than for females. ECRL overall is bigger and stronger muscle than ED, so this effect in percentage differences is better for ECRL. So, the highest value of mean percentage from maximally possible electric activity in the right ECRL was identified in females in playing with a bare hand (13.99±3.43), but the lowest one was revealed in the GrindClaw testing (7.84±1.38), i.e., lower by 44%, $p<0.001$. In males, the highest value was revealed for Product Y (7.81±1.20), but the lowest one in playing with a bare hand (6.27±1.98). Different types of computer mouse grip, movement habits, and the size of the wrist also might contribute to these differences. In ED muscle, this difference was also present but to a lesser extent. The highest percentage for the right ED muscle in males was observed in playing with a bare hand (13.85±3.07), then followed the trials of Product X (13.76±3.02; $p>0.05$), and the lowest activity was detected in the GrindClaw testing (11.11±2.84; p=0.001). In females, the highest value was identified in GrindClaw tests (16.03±3.33), then followed playing with a bare hand (15.09±3.28), but the lowest one was in the Product X trials (13.71±3.57).

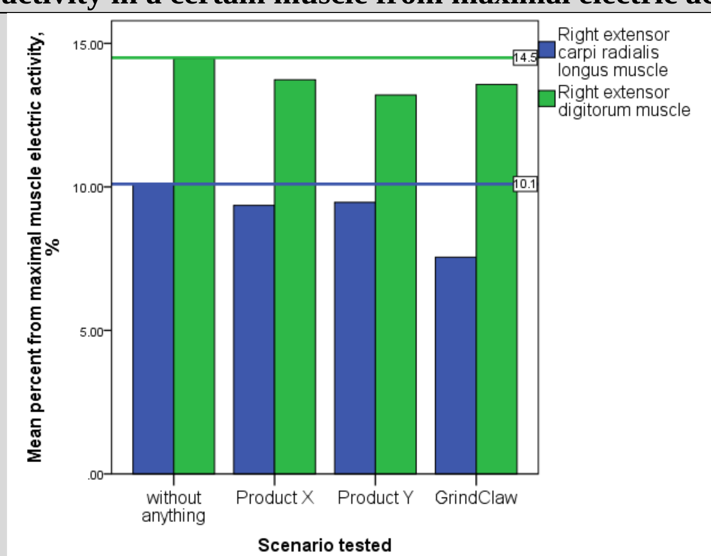
Some differences were noted also analysing data by sEMG measurement time (Figure 2.19). Electric activity parameters of the right ECRL muscle mainly slightly decreased at the end of the trials or were close to the parameters of the beginning of the test day, but for the right ED muscle, parameters slightly increased in all the tested scenarios except GrindClaw testing where parameters at the end were insignificantly lower than in the beginning (13.71±3.79 in the beginning vs. 13.43±4.16 at the end). All these changes could be explained by overload of muscles during the 3-hour-long intensive gaming.

Analysing sEMG data by manual dexterity tests (Figure 2.20), it can be concluded that the trend of the effect of tested products was quite similar to the one described above: significantly lower load for ECRL was revealed in GrindClaw tests in comparison with other scenarios with good reduction of the load in AngleShot, FourShot, Dodgeswitch and Swayswitch tests. In Product X testing, noticeable reduction of the muscle load was identified in DodgeSwitch and Swayswitch tests, but AngleShot test showed lesser reduction. In Product Y trials, the best reduction of the load was observed in AngleShot test. For the right ED muscle, the reduction of electric activity parameters was much less expressed. The most significant reduction of the load in ED muscle was observed in the GrindClaw testing for Dodgeswitch test. In Product Y testing, reduction was observed in Dodgeswitch, Blinktrack, and Suavetrack tests. In Product X tests, the reduction of electric activity was much less expressed.

More detailed analysis of sEMG data by products and dexterity tests is given in Annexes 1-4.

Overall, comparing sEMG data to manual dexterity tests, the correlation of them is visible quite well. Higher scores in manual dexterity tests correspond to lower muscle load in sEMG measurements, i.e., for good manual dexterity and gaming performance lower load of forearm extensor muscles is necessary. This can be achieved by positioning of the wrist close to the neutral position.

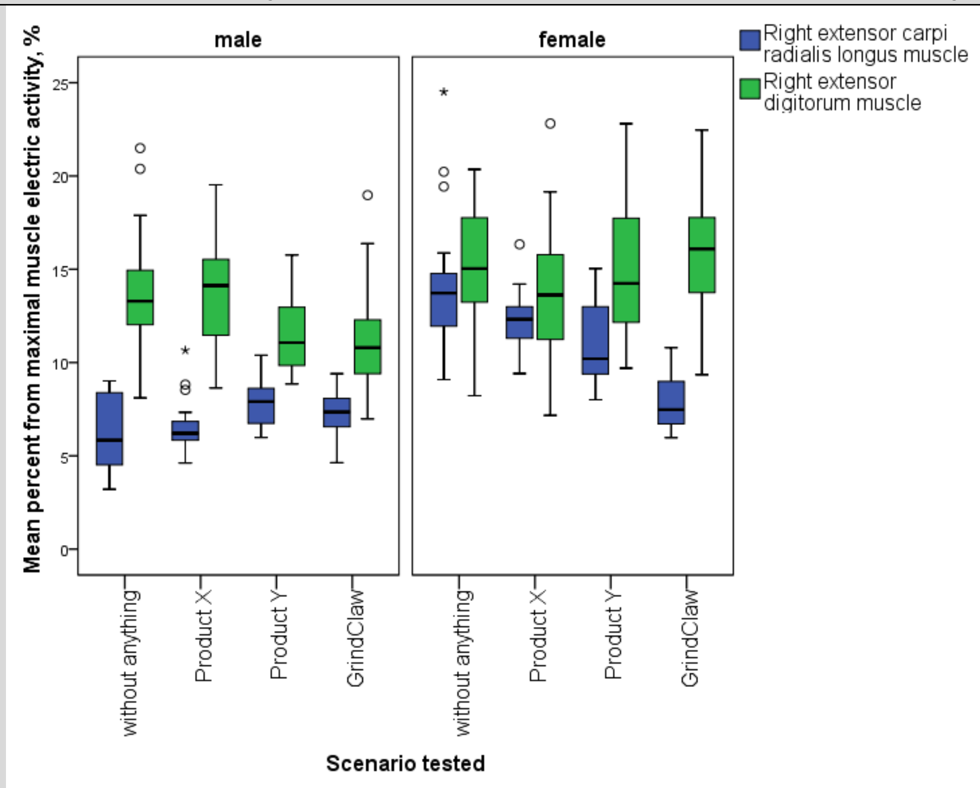
**Figure 2.16. Right forearm extensor muscle electric activity by muscles and tested scenarios (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)***




*Reference lines represent the mean value of electric activity in corresponding muscles for playing without any product (with bare hand; reference for other tested scenarios), blue line for the right extensor carpi radialis longus, green – for extensor digitorum muscle.

Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.17. Right forearm extensor muscle electric activity by gender, muscles, and tested scenarios (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)***




*Asterisks and circles represent outlying data.

**Figure 2.18. Maximal electrical activity by gender and muscle tested (mean, mV)**

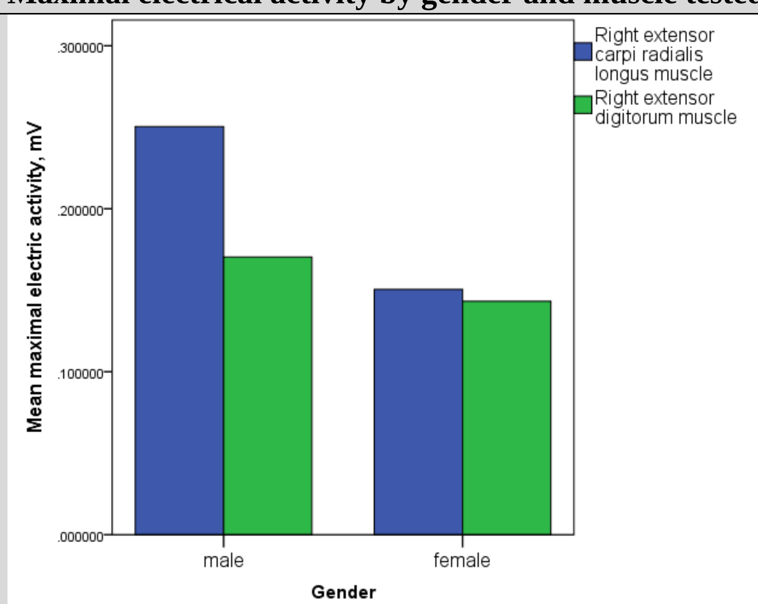
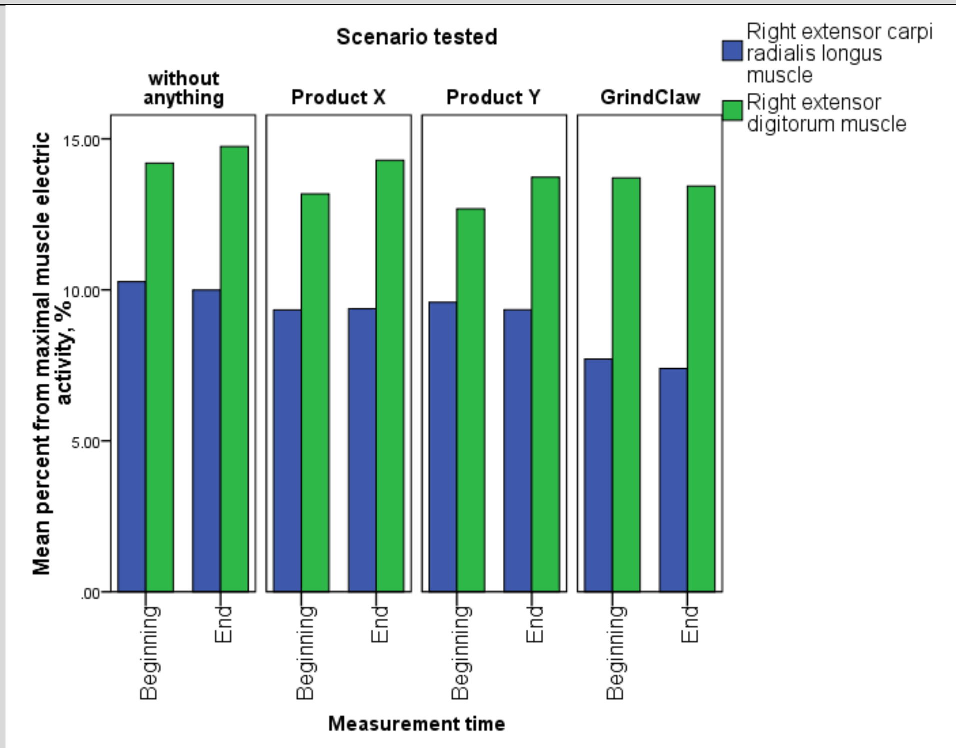
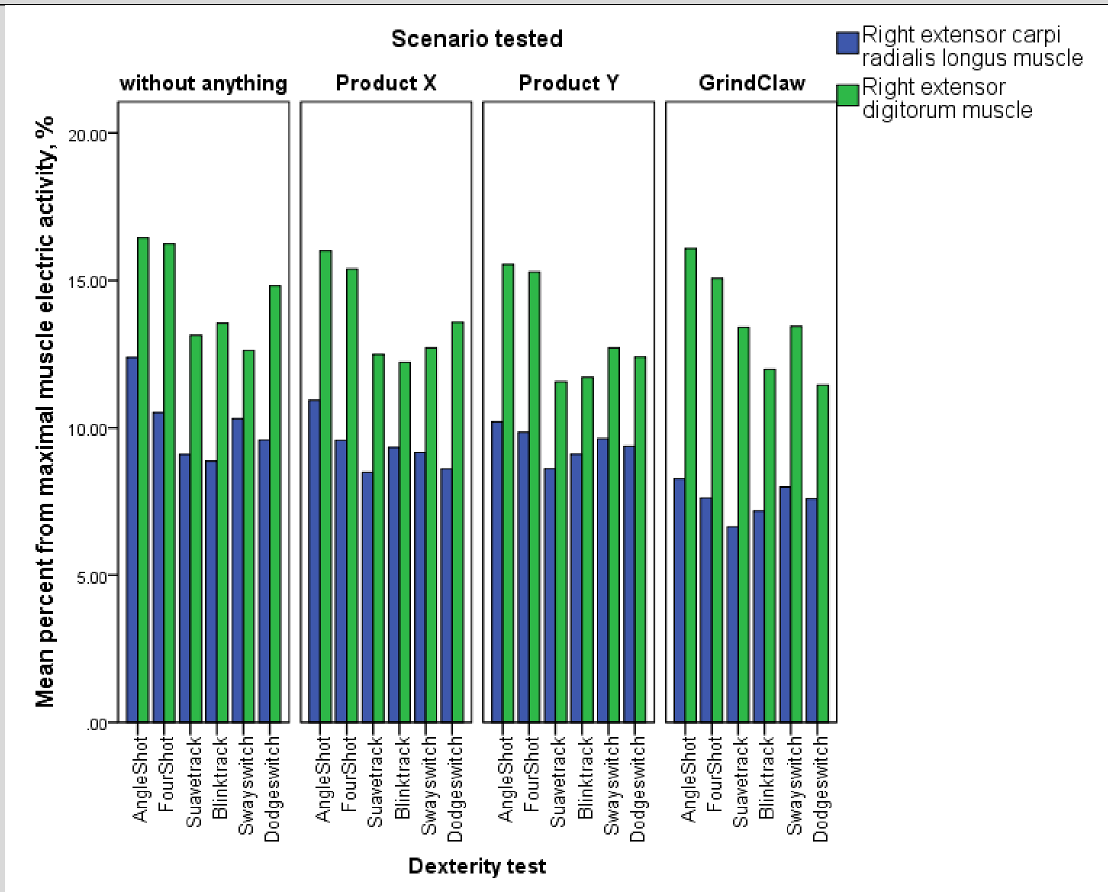


**Figure 2.19. Right forearm extensor muscle electric activity by measurement time, muscles, and tested scenarios (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)**



Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

**Figure 2.20. Right forearm extensor muscle electric activity by dexterity test, muscles, and tested scenarios (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)**




**Conclusions and recommendations:**

● Standardized manual dexterity tests have shown the dependence of gaming performance on ergonomic setup of wrist support. The increase of total score by 14.6% was observed in gaming with GrindClaw glove v5 prototype in comparison with playing without any product (18406.1 ±1067.1 for GrindClaw vs. 16065.1 ±1449.5 points for playing with a bare hand; p=0.022) or using other products (17347.3 ±596.3 for Product X and 16922.9 ±1133.9 for Product Y), i.e., improvement of fine motor function of the wrist was revealed. The improvement of gaming performance in GrindClaw testing varied in different dexterity tests from +8.1% in Dodgeswitch test till 37.9% in Suavetrack test.

● Wrist skin moisture measurements have shown that the material of GrindClaw v5 prototype is breathable and preserves low humidity on the dorsal surface of the wrist and palmar surface of wrist basement while using computer mouse (TEWL in GrindClaw tests was lower by 31.1% at wrist basement and by 18% on the dorsal surface of the wrist comparing with playing without any product). On the palmar surface of the wrist, slightly increased moisture after intensive playing was observed (+11.1% comparing with playing without any product).

● It is advised to use more breathable material instead of perforated leather element on the palmar surface of the GrindClaw glove.

● It was found out that GrindClaw glove v5 prototype of appropriate size insignificantly compresses soft tissues of the wrist in projection sites of the seams, but the total effect of prolonged computer mouse use on peripheral microcirculation is similar to the effects of other tested scenarios and did not differ significantly. GrindClaw and Product Y gloves kept heat in the wrist for a slightly longer time during the first gaming hour than in playing without any special product.

● It can be concluded that GrindClaw v5 prototype is safe for blood circulation and soft tissues in the wrist during prolonged use.

● Soft fabric over the seams, cushioning, invisible soft seams, or seamless construction of the glove are advisable for GrindClaw glove to reduce pressure of seams on the wrist skin.

● Results of sEMG measurements have revealed an average 25.5% lower load for extensor carpi radialis longus muscle and 6.2% for extensor digitorum muscles using GrindClaw v5 glove prototype in comparison with playing without any product for wrist support (mean electric activity in ECRL 7.55±1.32 in GrindClaw testing vs. 10.13±4.78 in playing with a bare hand, $p<0.001$; in ED 13.57±3.94 vs. 14.47±3.20 respectively, $p=0.034$). Product X also has shown decrease in muscle load (by 7.7% in ECRL and by 5.1% in ED), i.e., at a lesser extent than GrindClaw. Product Y reduced load for ECRL by 6.6% and for ED by 8.8%.

● The highest load for the right extensor carpi radialis longus (10.13±4.78) and extensor digitorum muscles (14.47±3.20) was identified in playing without any special wrist support just using horizontal computer mouse. This indicates a high risk for muscle overload while playing and unfavourable health effects in the long term.

● Higher scores in manual dexterity tests correspond to lower muscle load in sEMG measurements. Lower load in muscles provides better blood supply, longer successful work, and less tiredness, i.e., for good manual dexterity and gaming performance lower tension in forearm extensor muscles is necessary. This can be achieved by positioning of the wrist close to the neutral position.

● Data from manual dexterity tests in combination with sEMG and thermography results have confirmed that usage of specific wrist support while playing certain games can improve distinct movements and performance of the gamer.

● In the current study, data of only 4 individuals were evaluated, some individual differences were observed. To achieve better statistical power of the results, it would be advisable to test more people.

Study conducted and evaluation made by

**Jeļena Reste** MD, PhD
Associated professor, lead researcher
Institute of Occupational Safety and Environmental Health
Department of Occupational and Environmental Medicine
Rīga Stradiņš University
e-mail jelena.reste@rsu.lv

**Alise Guļājeva** MD
Scientific assistant
Institute of Occupational Safety and Environmental Health
Rīga Stradiņš University

30.01.2023.

Signature not validated

Digitally signed by JEĻENA RESTE
Date: 2023.01.30 10:26:21 EET

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

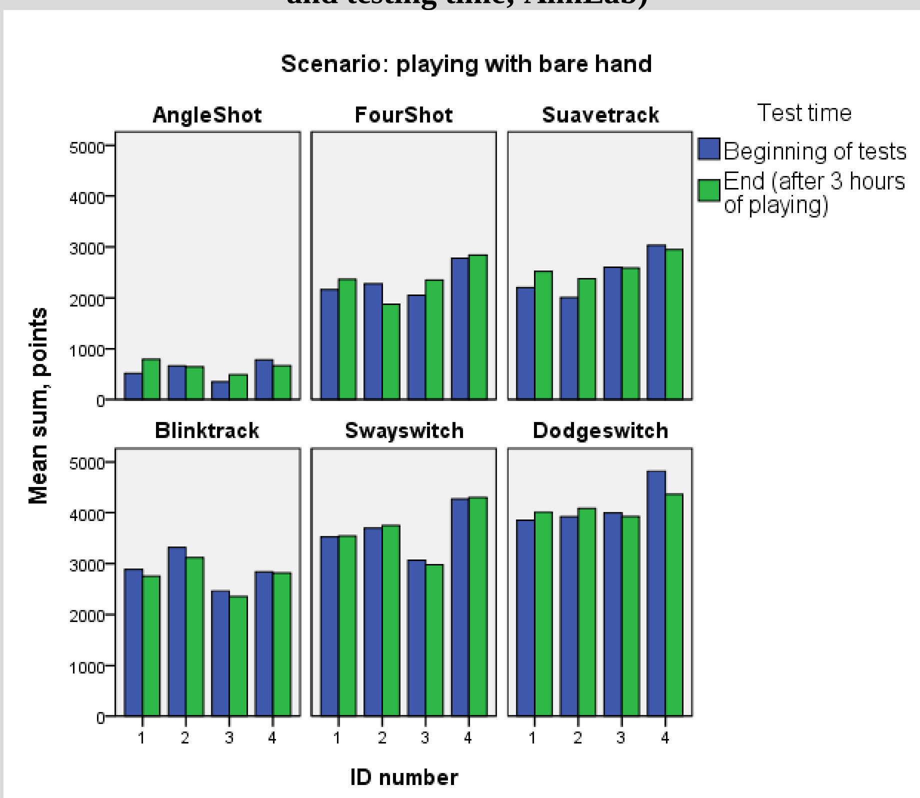
**Annexes**

# Test results by tested scenario

## Annex 1. Playing with a bare hand without any product

### I. Results of manual dexterity testing

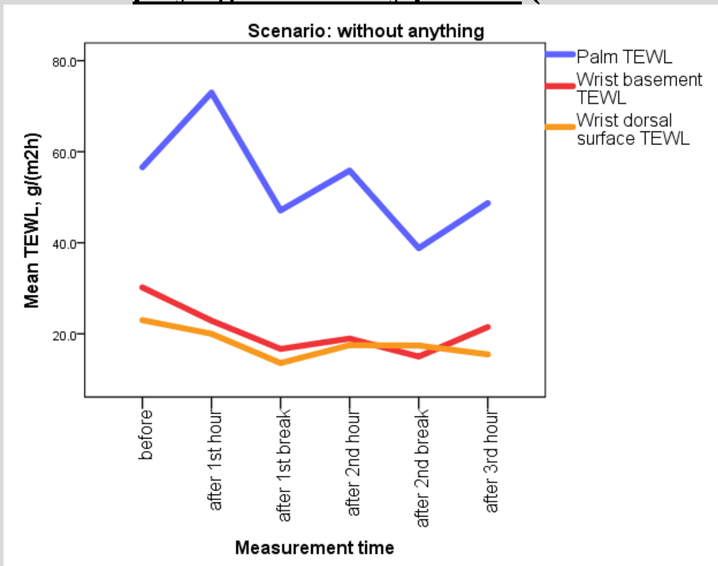
**Annex 1. Figure 1. Test results of the fine motor function of the wrist in playing without any product (mean sum of points from 3 runs in corresponding dexterity test by dexterity test, gamer ID number and testing time; AimLab)**



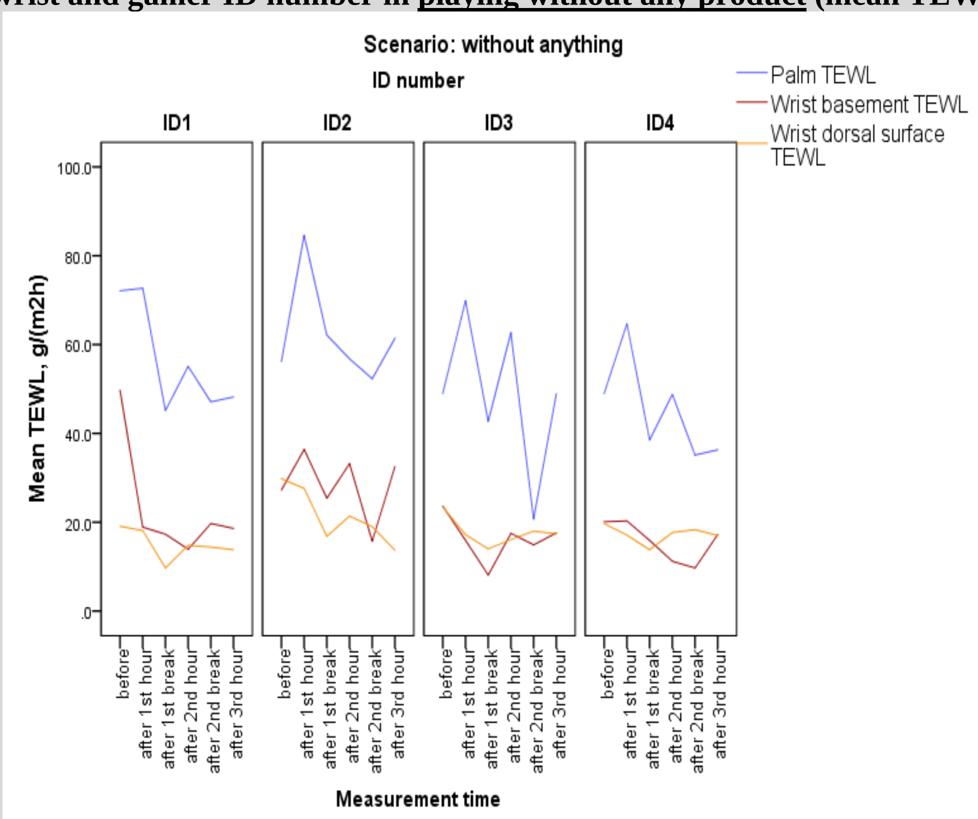
Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## II. Results of wrist skin moisture testing

**Annex 1. Figure 2.1. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist in <u>playing without any product</u> (mean TEWL, g/(m²h)**



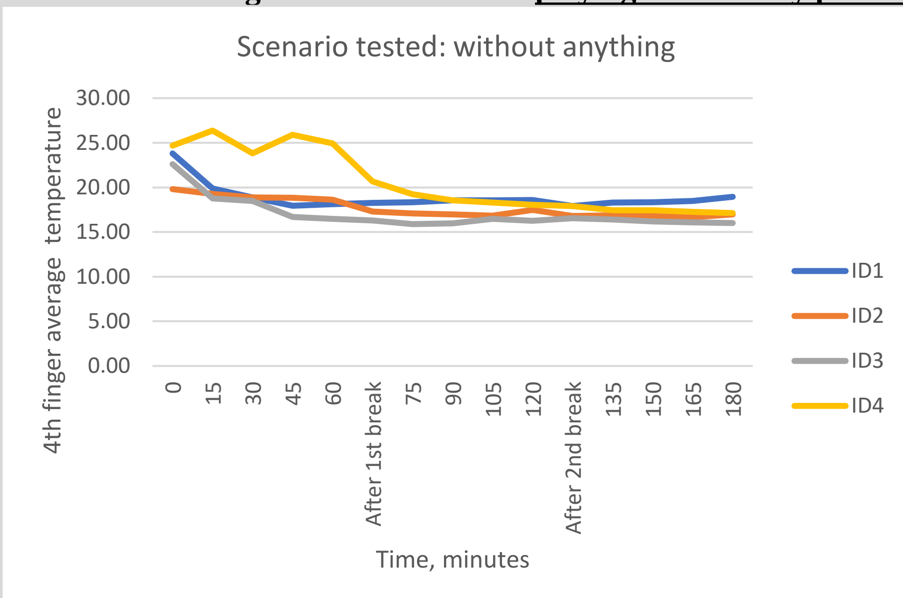

**Annex 1. Figure 2.2. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist and gamer ID number in <u>playing without any product</u> (mean TEWL, g/(m²h)**



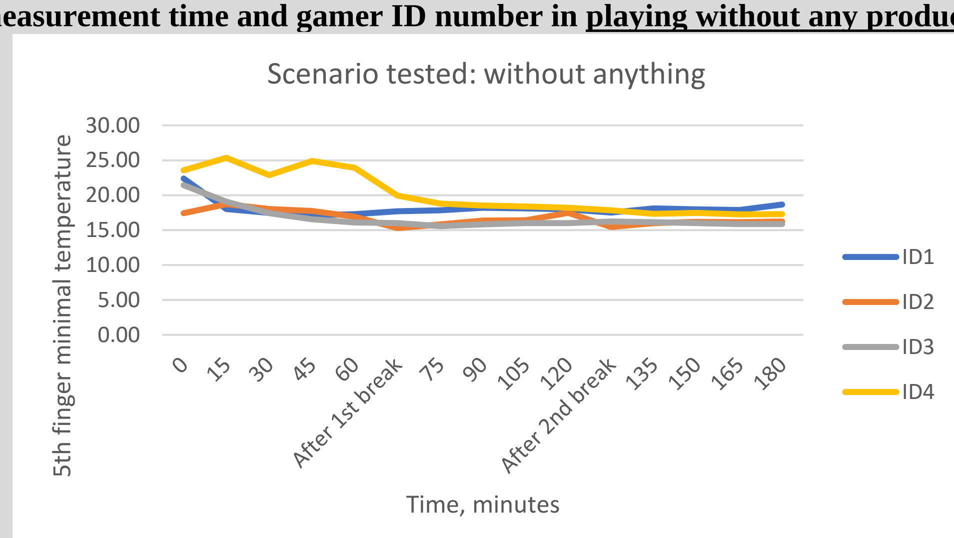
Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## III. Results of thermography

**Annex 1. Figure 3.1. The dynamics of mean skin surface temperature of the right wrist 4th finger by measurement time and gamer ID number in playing without any product (°C)**

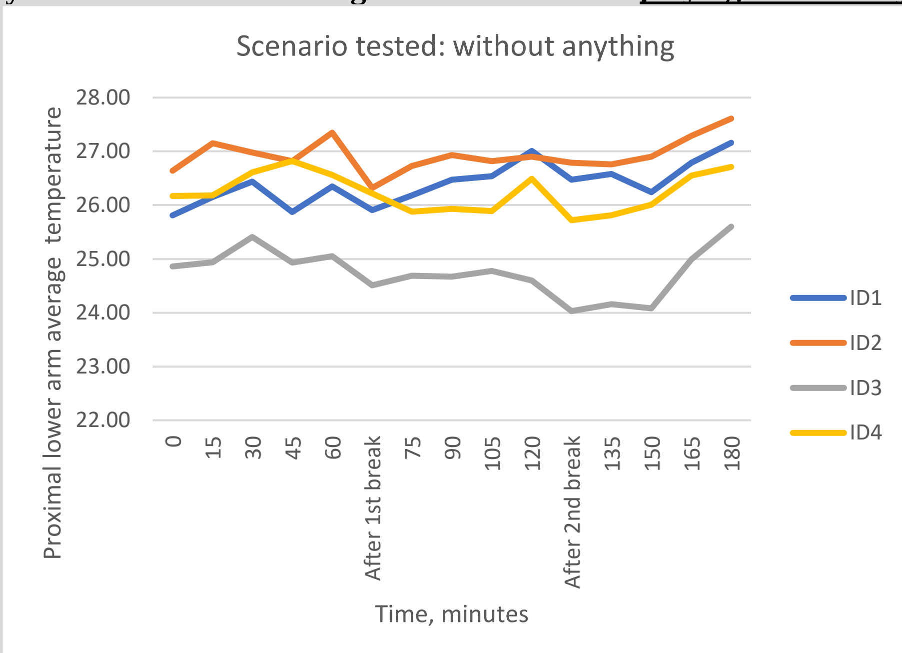



**Annex 1. Figure 3.2. The dynamics of minimal skin surface temperature in the right wrist 5th finger by measurement time and gamer ID number in playing without any product (°C)**



Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

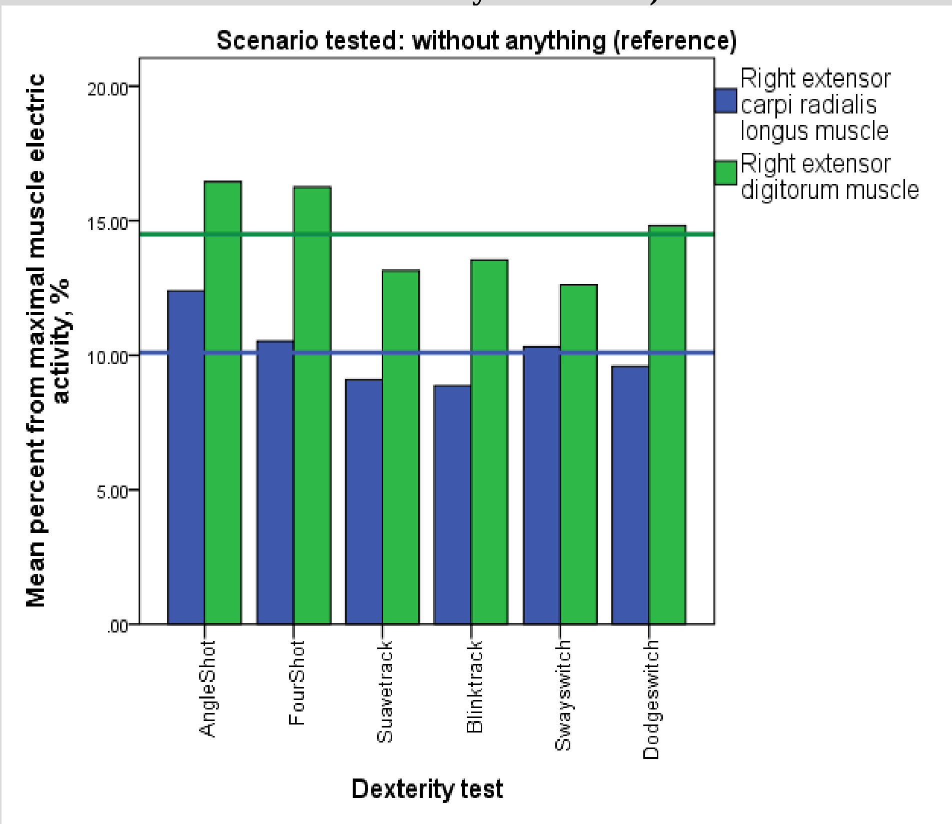
**Annex 1. Figure 3.3. The dynamics of mean skin surface temperature in the lateral proximal part of the forearm by measurement time and gamer ID number in <u>playing without any product</u> (°C)**



Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## IV. Results of surface electromyography

**Annex 1. Figure 4.1. Right forearm extensor muscle electric activity by muscles and dexterity tests in <u>playing without any product</u> (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)***



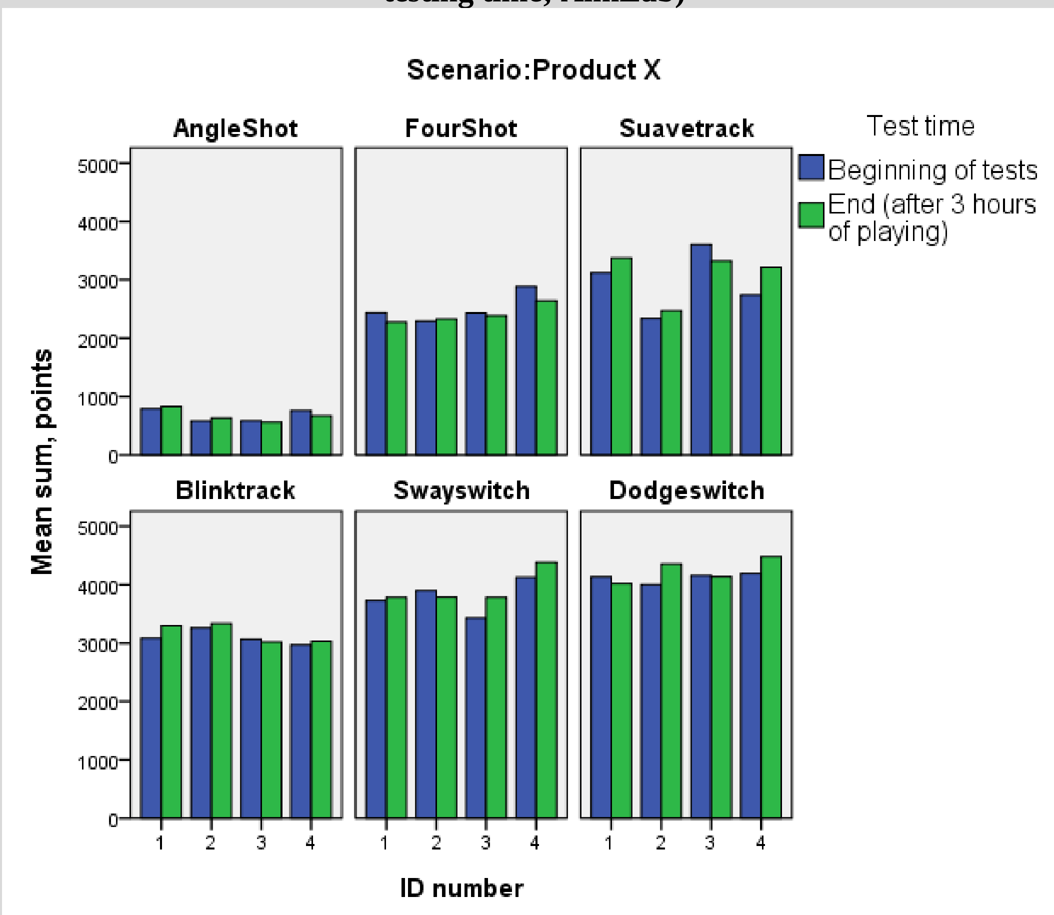

*Reference lines indicate mean value of parameters in all tests for right extensor carpi radialis longus muscle (blue line) and right extensor digitorum muscle (green line).

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

# Annex 2. Product X for wrist support testing

## I. Results of manual dexterity testing

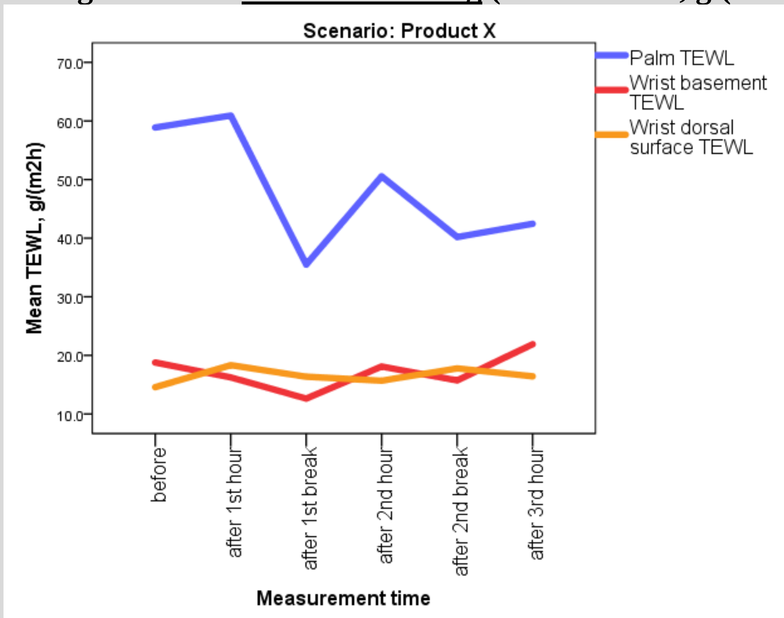
**Annex 2. Figure 1. Test results of the fine motor function of the wrist in <u>Product X</u> testing (mean sum of points from 3 runs in corresponding dexterity test by dexterity test, gamer ID number and testing time; AimLab)**



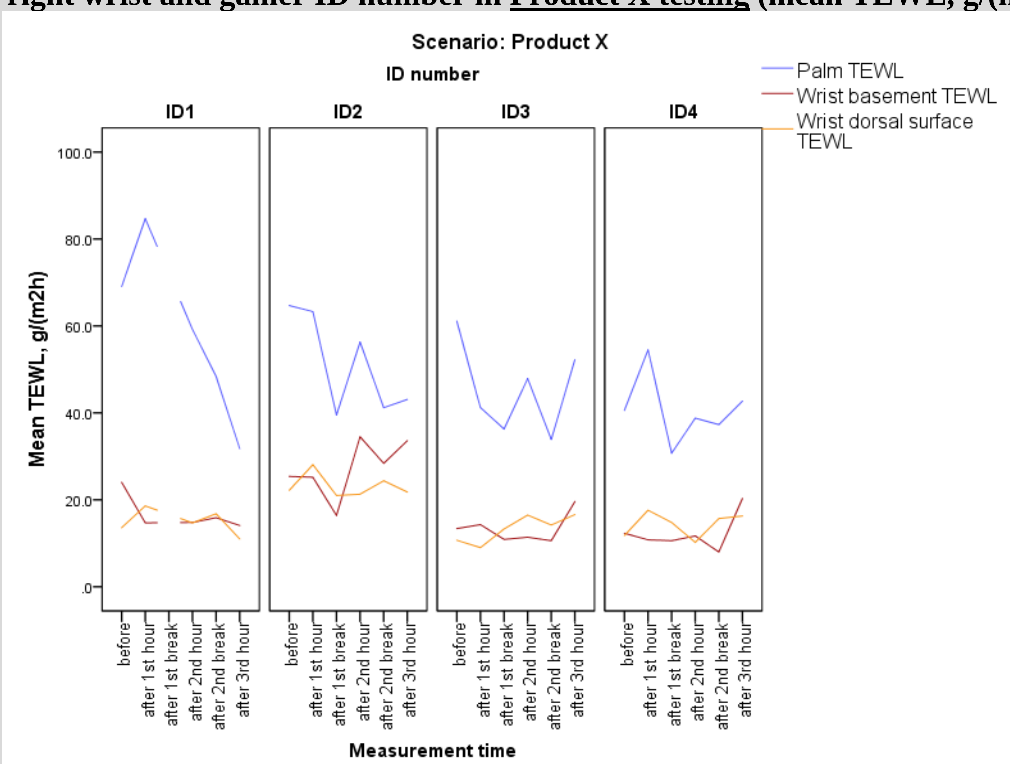
Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## II. Results of wrist skin moisture testing

**Annex 2. Figure 2.1. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist in <u>Product X testing</u> (mean TEWL, g/(m$^2$h)**

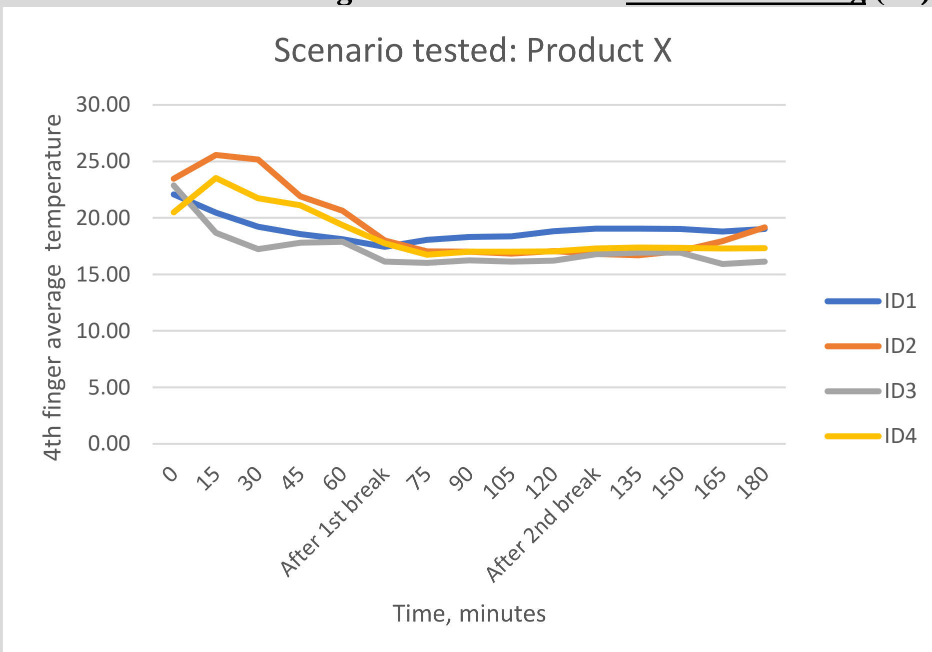



**Annex 2. Figure 2.2. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist and gamer ID number in <u>Product X testing</u> (mean TEWL, g/(m$^2$h)**

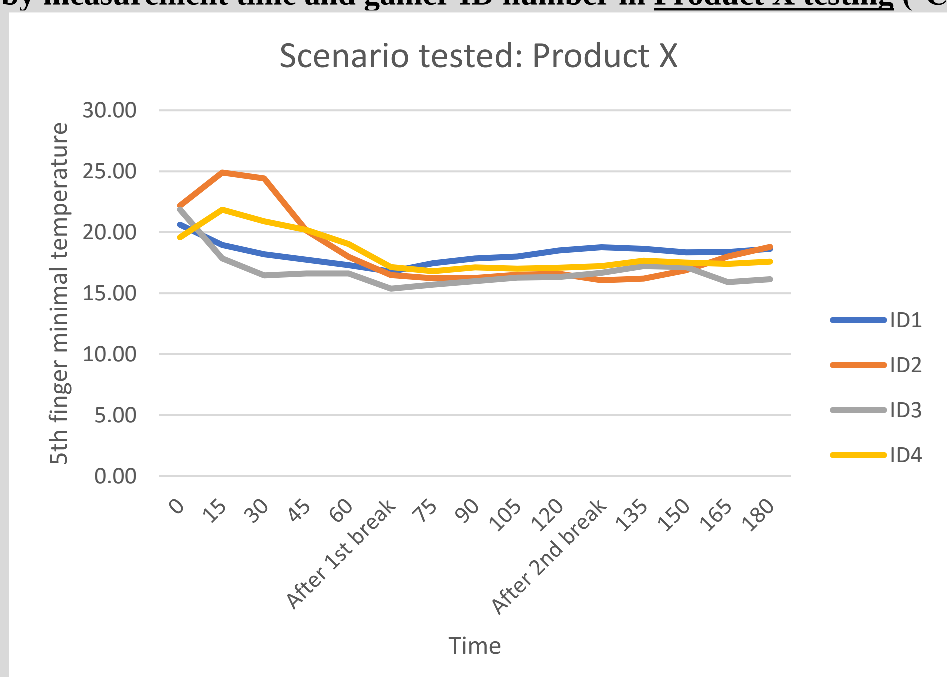


## III. Results of thermography

**Annex 2. Figure 3.1. The dynamics of mean skin surface temperature of the right wrist 4th finger by measurement time and gamer ID number in Product X testing (°C)**



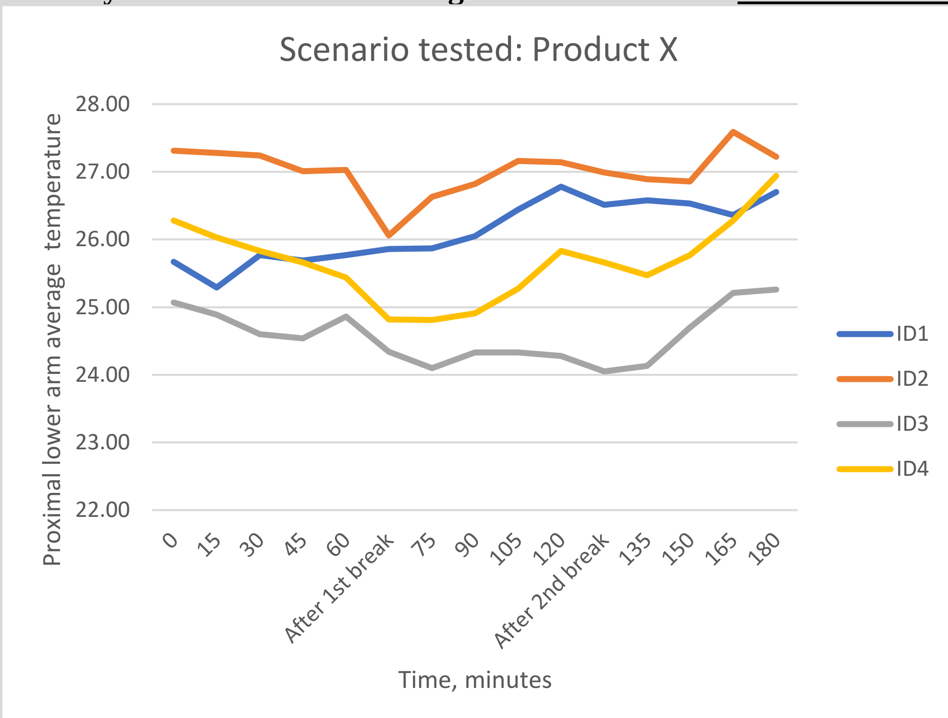

**Annex 2. Figure 3.2. The dynamics of minimal skin surface temperature in the right wrist 5th finger by measurement time and gamer ID number in Product X testing (°C)**



RĪGAS STRADIŅA UNIVERSITĀTE

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

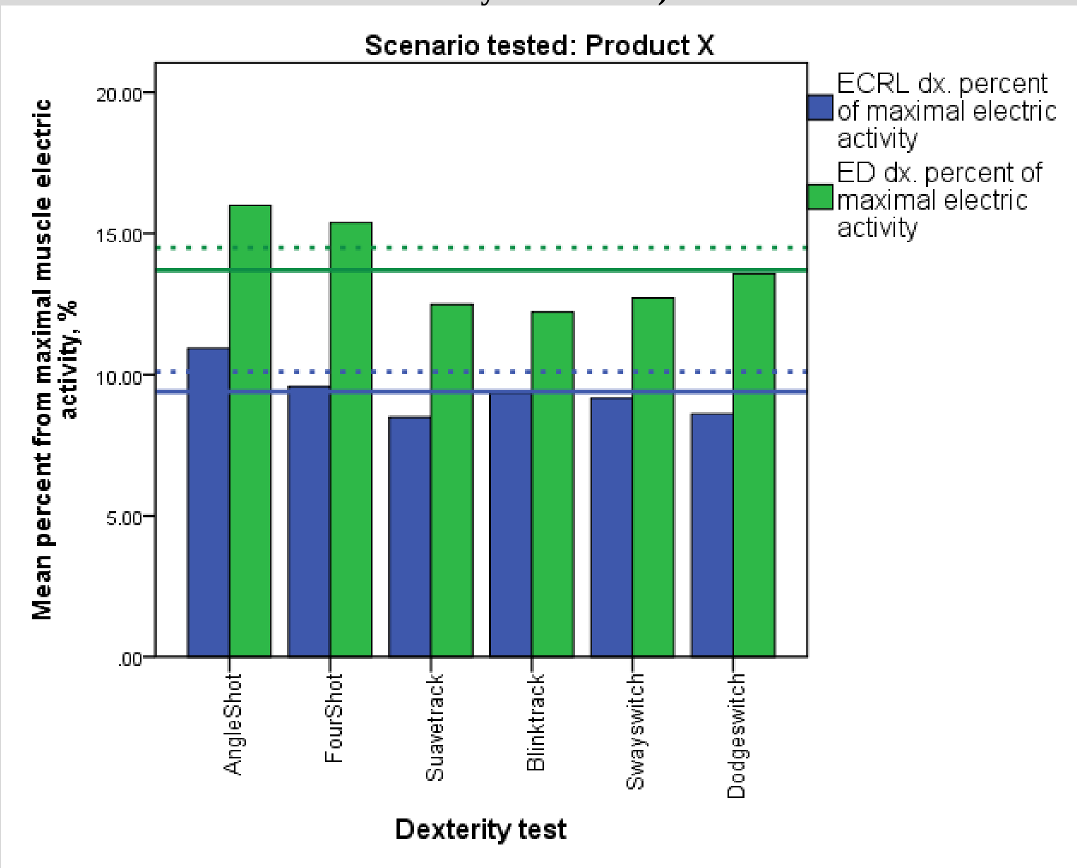
**Annex 2. Figure 3.3. The dynamics of mean skin surface temperature in the lateral proximal part of the forearm by measurement time and gamer ID number in Product X testing (°C)**



Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## IV. Results of surface electromyography

**Annex 2. Figure 4.1. Right forearm extensor muscle electric activity by muscles and dexterity tests in Product X testing (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)***



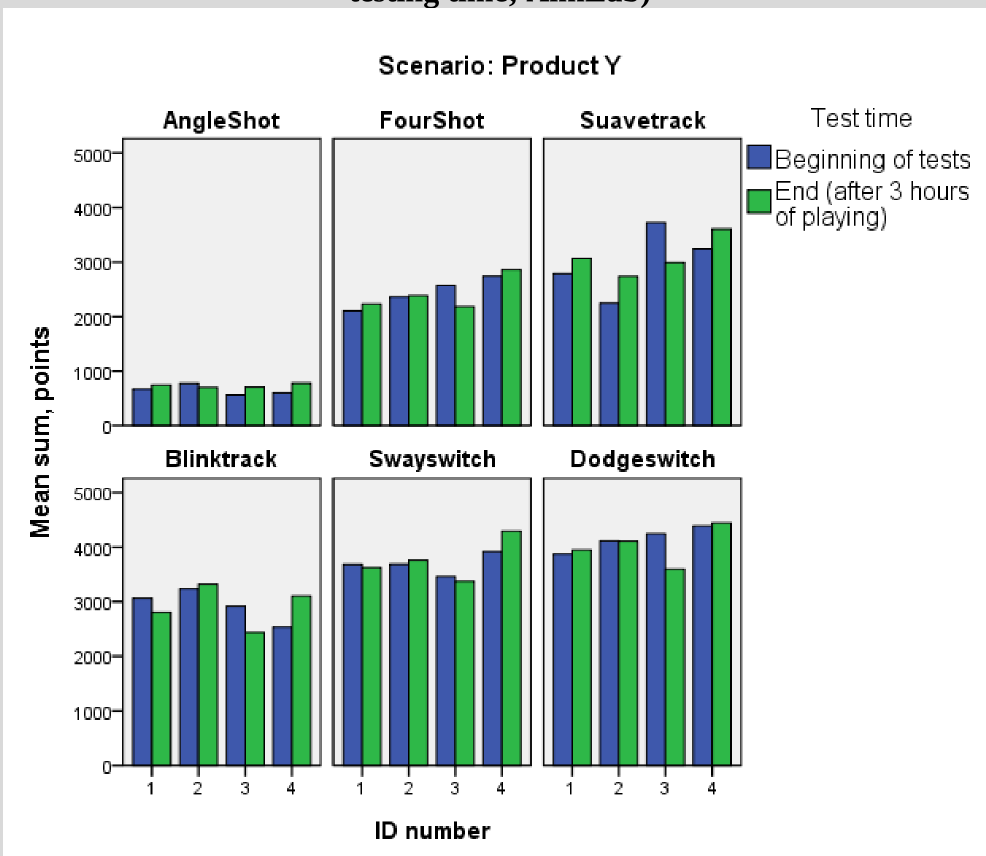

*Reference lines indicate mean value of parameters in all tests for right extensor carpi radialis longus muscle (blue lines) and right extensor digitorum muscle (green lines): solid line for mean value in current scenario tested; dashed line for reference with tests performed without any product or wrist support (playing with bare hand and horizontal computer mouse).

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

# Annex 3. Product Y glove testing

## I. Results of manual dexterity testing

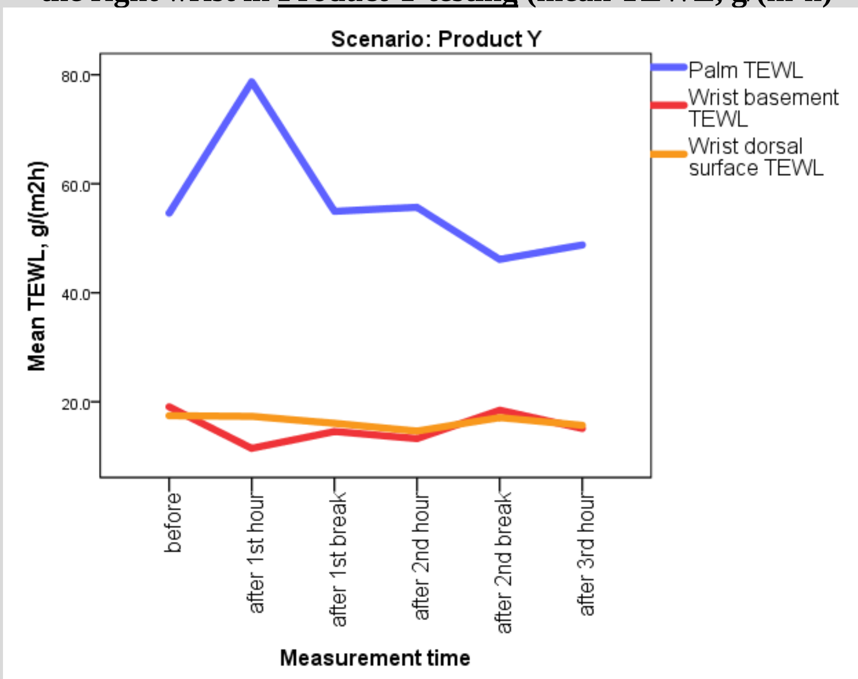
**Annex 3. Figure 1. Test results of the fine motor function of the wrist in <u>Product Y</u> testing (mean sum of points from 3 runs in corresponding dexterity test by dexterity test, gamer ID number and testing time; AimLab)**



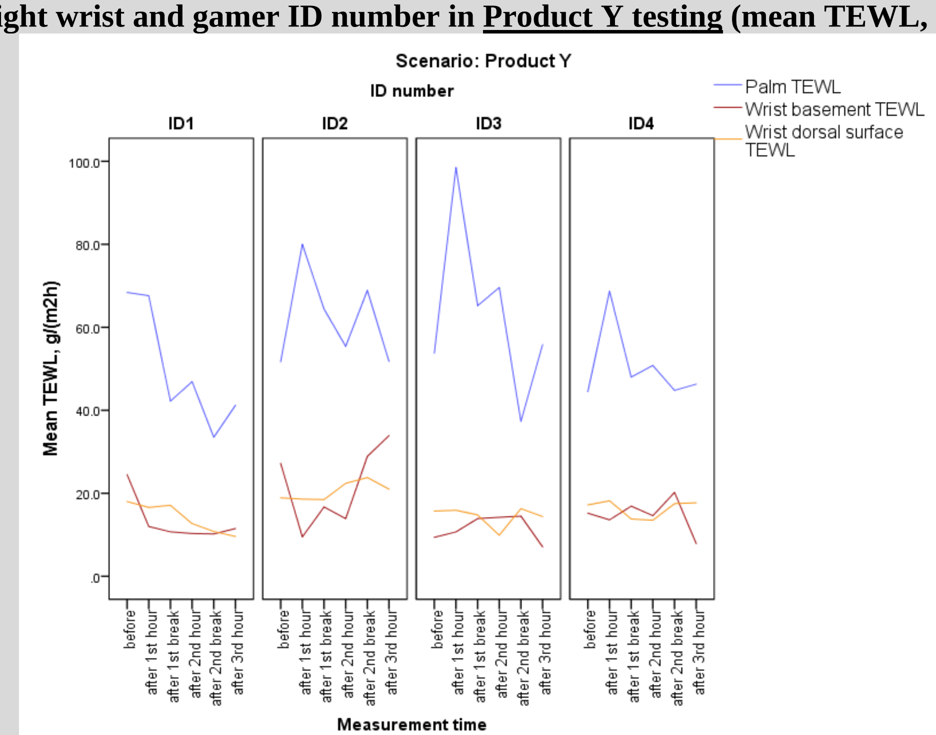
Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## II. Results of wrist skin moisture testing

**Annex 3. Figure 2.1. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist in Product Y testing (mean TEWL, g/(m$^2$h)**



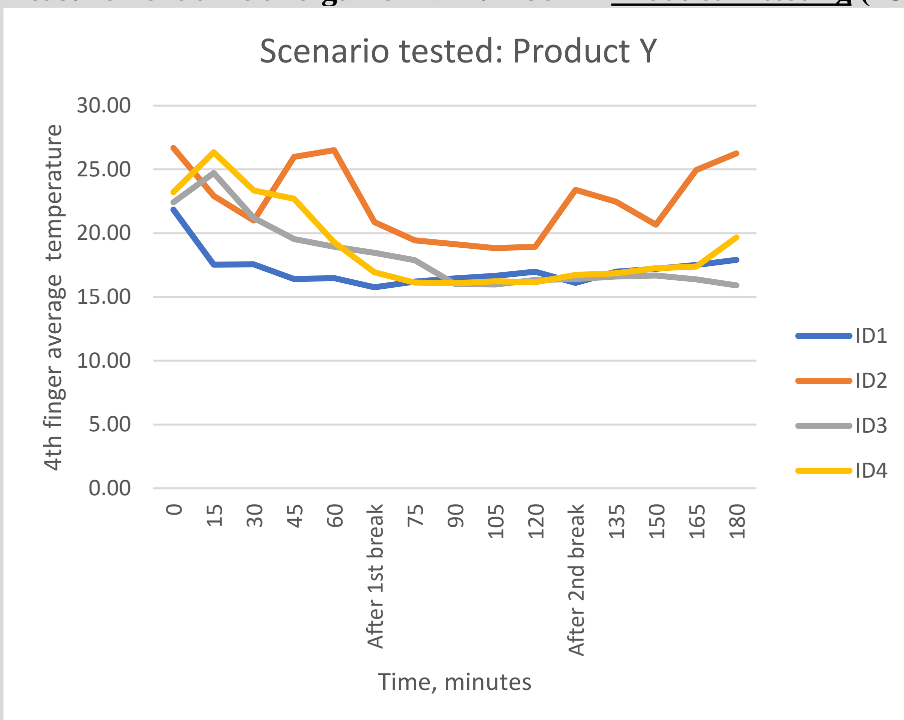

**Annex 3. Figure 2.2. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist and gamer ID number in Product Y testing (mean TEWL, g/(m$^2$h)**



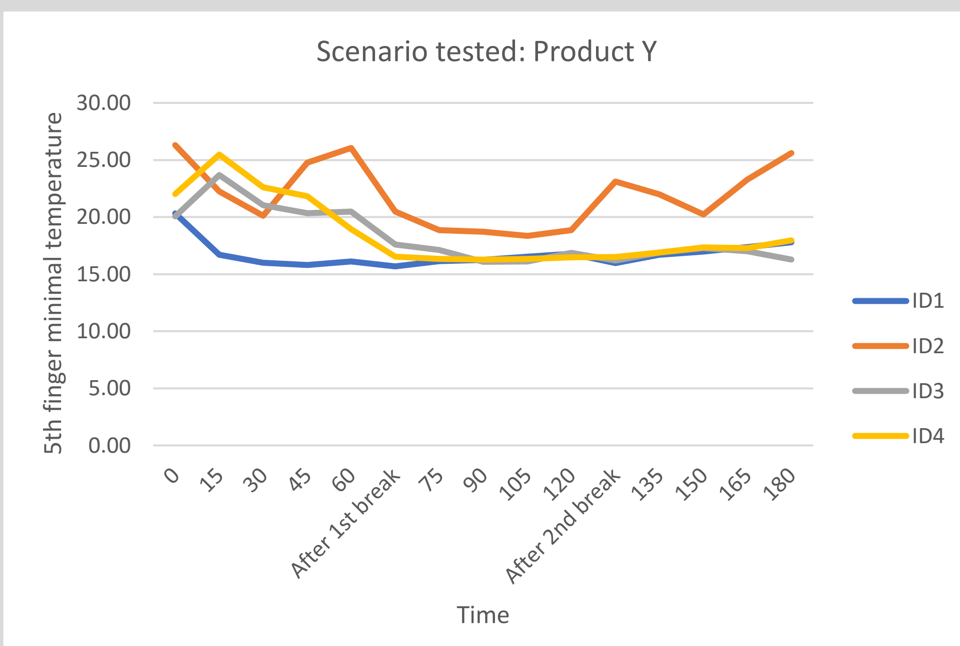
Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## III. Results of thermography

**Annex 3. Figure 3.1. The dynamics of mean skin surface temperature of the right wrist 4th finger by measurement time and gamer ID number in Product Y testing (°C)**

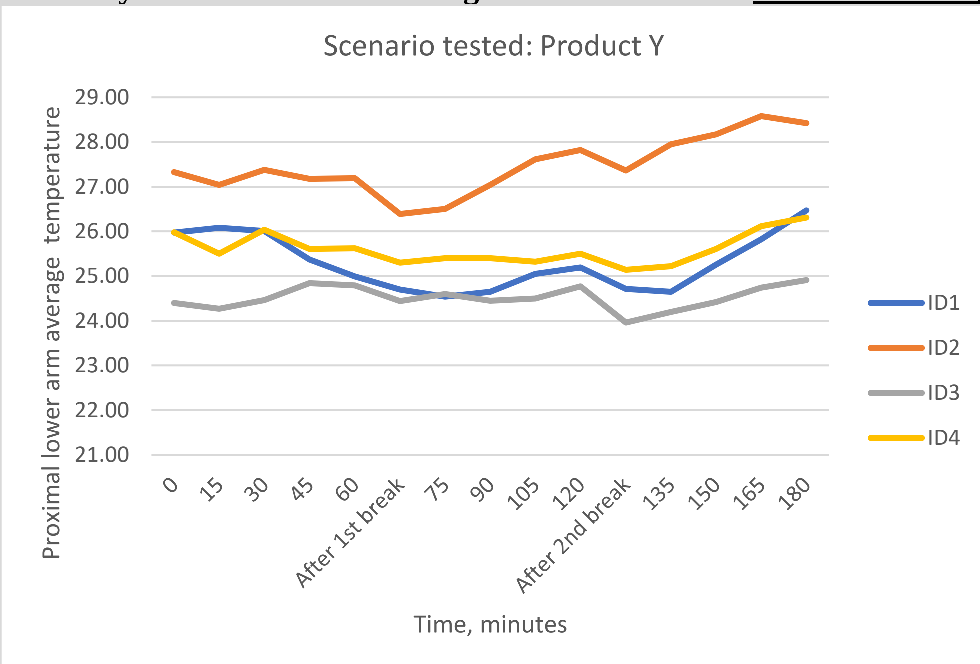



**Annex 3. Figure 3.2. The dynamics of minimal skin surface temperature in the right wrist 5th finger by measurement time and gamer ID number in Product Y testing (°C)**



Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

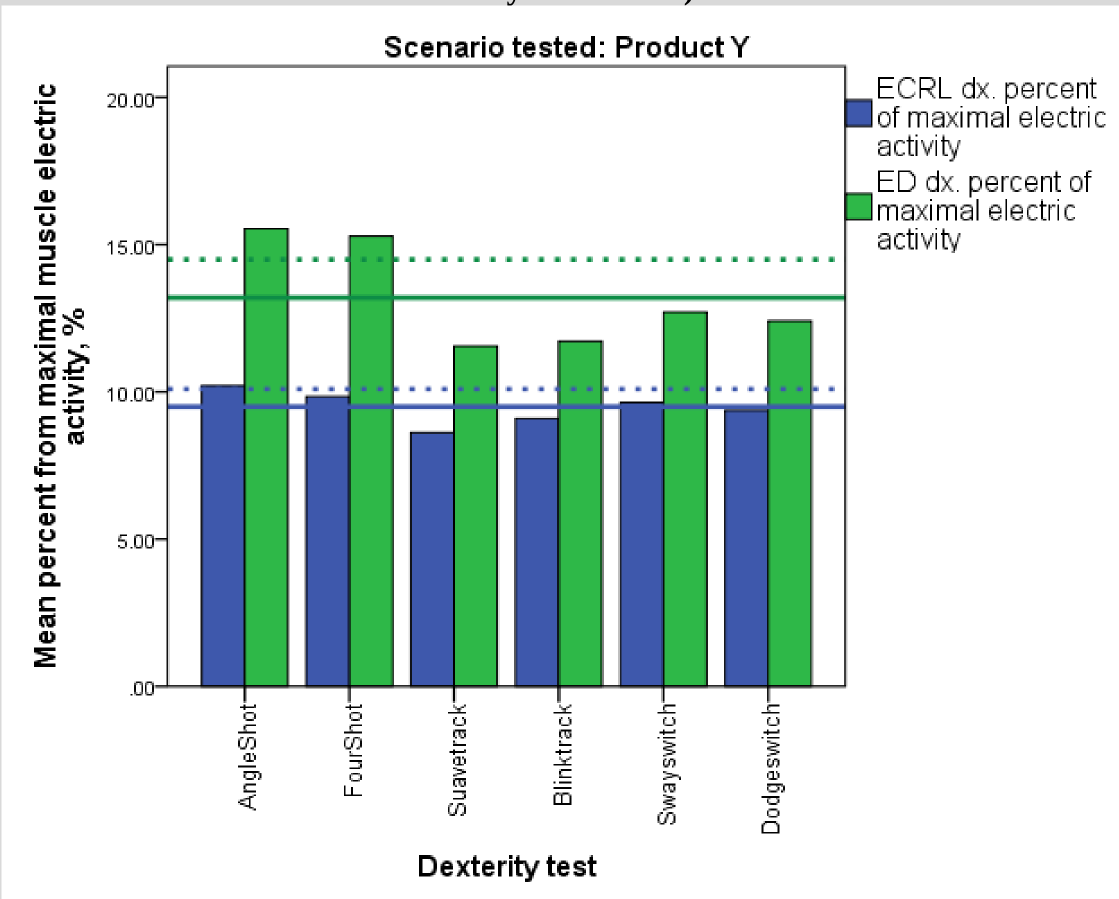
**Annex 3. Figure 3.3. The dynamics of mean skin surface temperature in the lateral proximal part of the forearm by measurement time and gamer ID number in Product Y testing (°C)**



Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## IV. Results of surface electromyography

**Annex 3. Figure 4.1. Right forearm extensor muscle electric activity by muscles and dexterity tests in <u>Product Y testing</u> (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)***

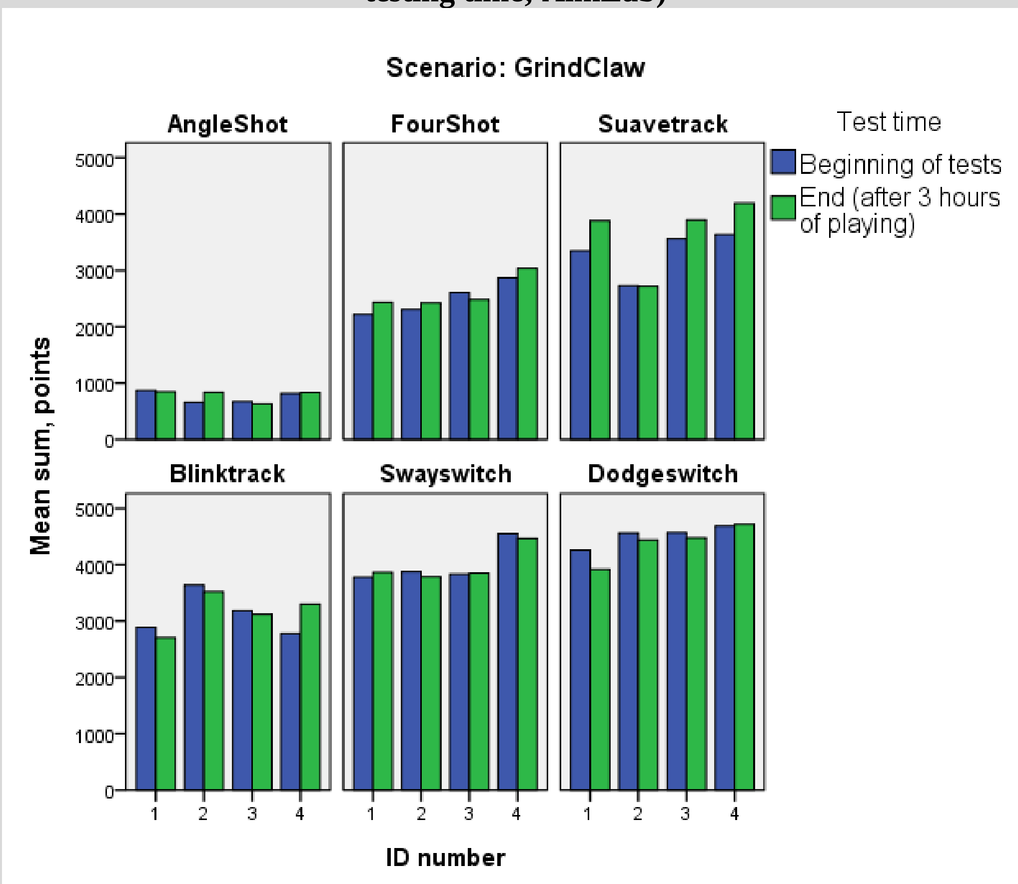



*Reference lines indicate mean value of parameters in all tests for right extensor carpi radialis longus muscle (blue lines) and right extensor digitorum muscle (green lines): solid line for mean value in current tested scenario; dashed line for reference with tests performed without any product or wrist support (playing with bare hand and horizontal computer mouse).

## Annex 4. GrindClaw glove testing

### I. Results of manual dexterity testing

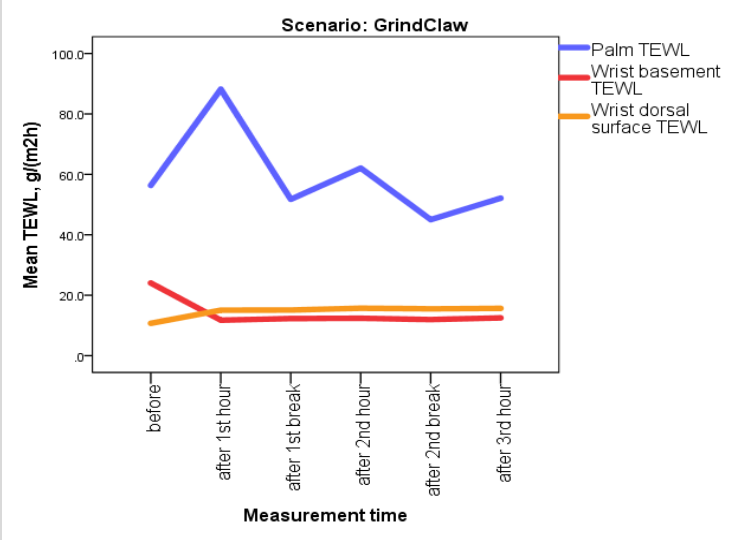
**Annex 4. Figure 1. Test results of the fine motor function of the wrist in GrindClaw testing (mean sum of points from 3 runs in corresponding dexterity test by dexterity test, gamer ID number and testing time; AimLab)**



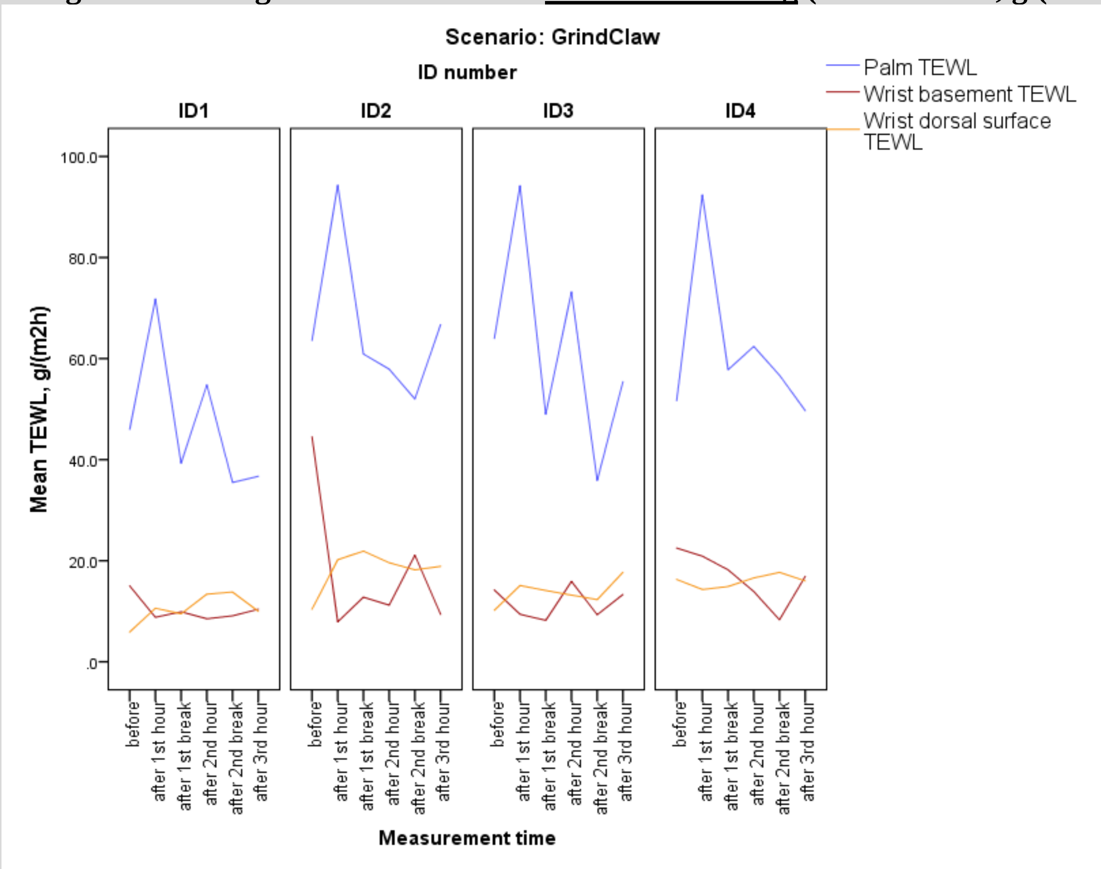
Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## II. Results of wrist skin moisture testing

**Annex 4. Figure 2.1. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist in GrindClaw testing (mean TEWL, g/(m$^2$h)**



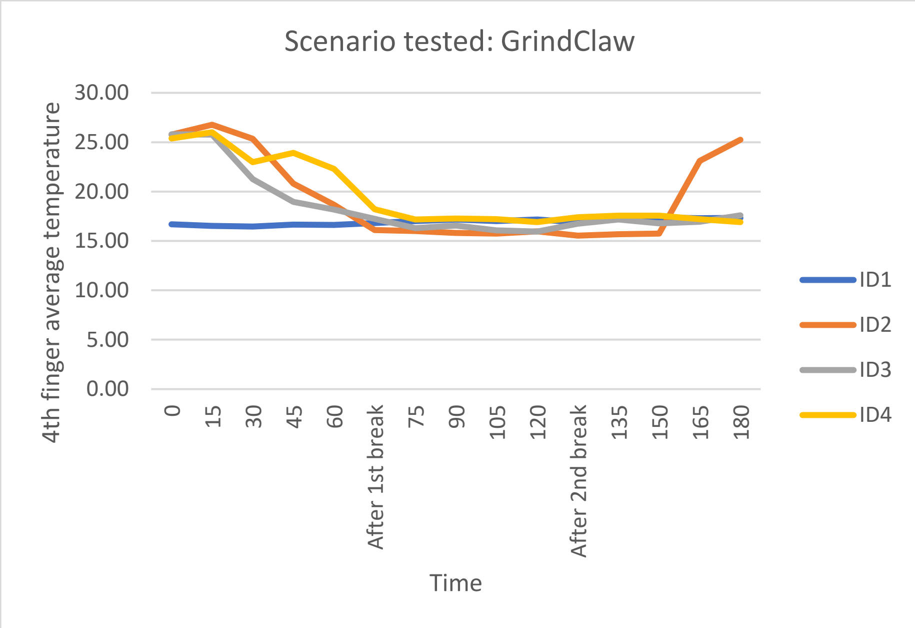

**Annex 4. Figure 2.2. Dynamics of transepidermal water loss (TEWL) by measurement location in the right wrist and gamer ID number in GrindClaw testing (mean TEWL, g/(m$^2$h)**



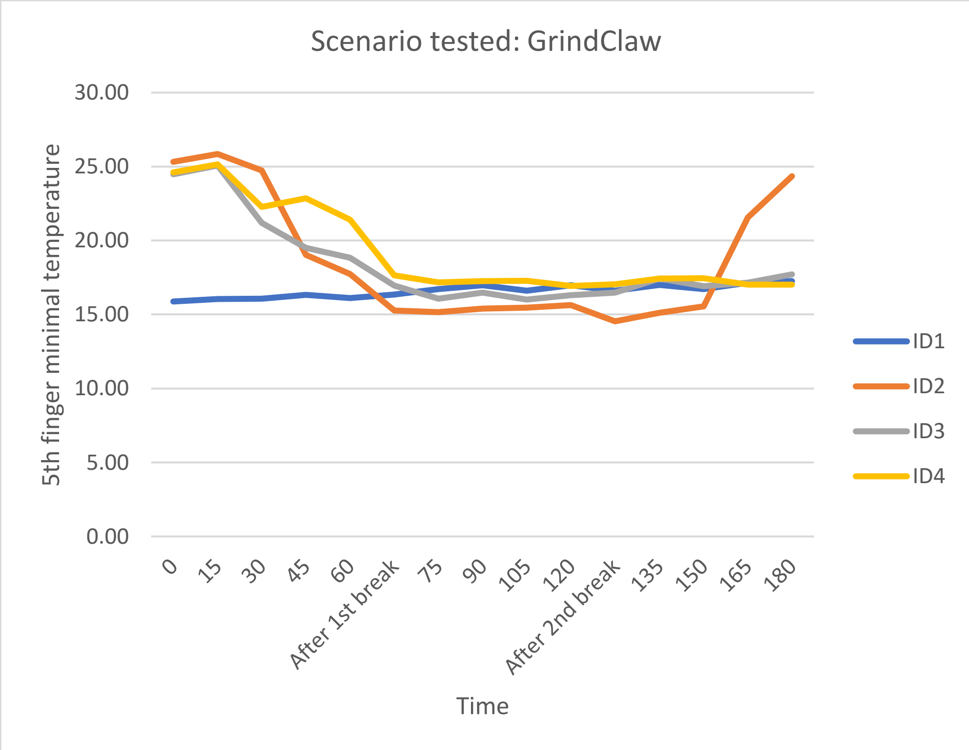
Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## III. Results of thermography

**Annex 4. Figure 3.1. The dynamics of mean skin surface temperature of the right wrist 4th finger by measurement time and gamer ID number in <u>GrindClaw testing</u> (°C)**

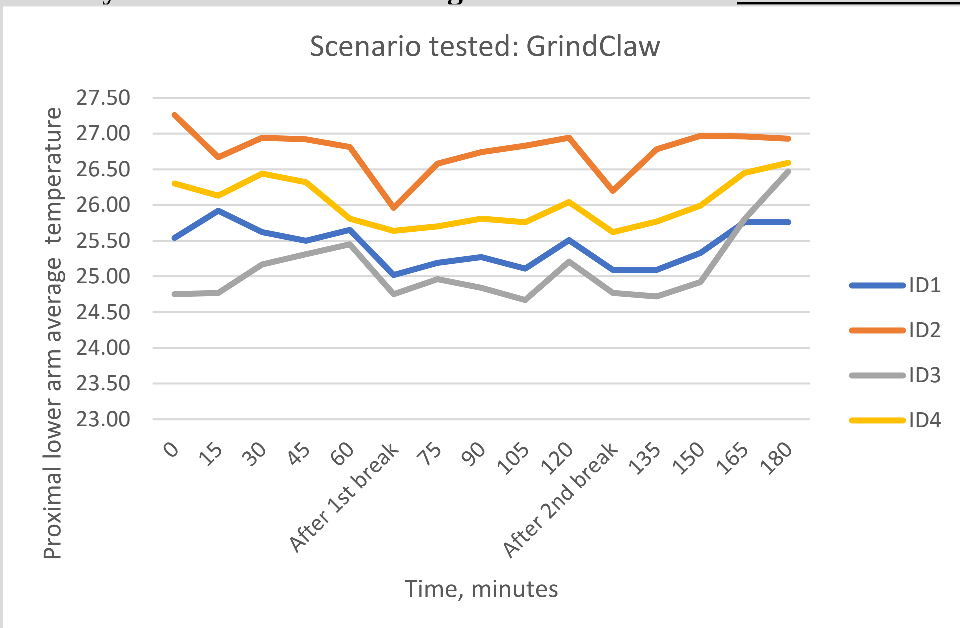



**Annex 4. Figure 3.2. The dynamics of minimal skin surface temperature in the right wrist 5th finger by measurement time and gamer ID number in <u>GrindClaw testing</u> (°C)**



Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

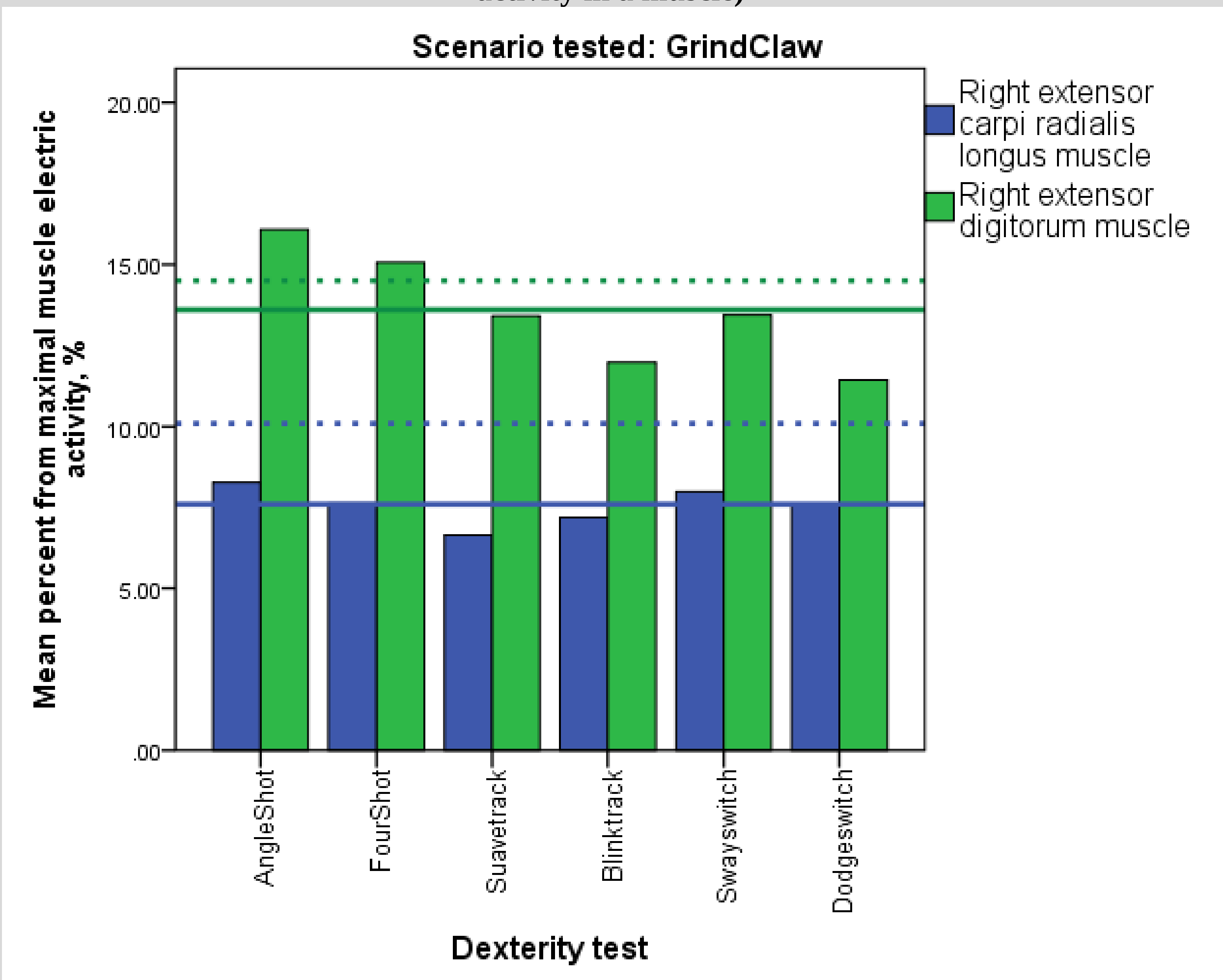
**Annex 4. Figure 3.3. The dynamics of mean skin surface temperature in the lateral proximal part of the forearm by measurement time and gamer ID number in <u>GrindClaw testing</u> (°C)**



Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

## IV. Results of surface electromyography

**Annex 4. Figure 4.1. Right forearm extensor muscle electric activity by muscles and dexterity tests in GrindClaw testing (mean percent of electric activity in a certain muscle from maximal electric activity in a muscle)***




*Reference lines indicate mean value of parameters in all tests for right extensor carpi radialis longus muscle (blue lines) and right extensor digitorum muscle (green lines): solid line for mean value in current tested scenario; dashed line for reference with tests performed without any product or wrist support (playing with bare hand and horizontal computer mouse).

Rīga Stradiņš University
INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

# Annex 5. Instructions for study participants and informed written consent (in Latvian)

**Atgādne pētījuma dalībniekam**

Pētījuma ietvaros 4 atsevišķās dienās, kamēr Jūs spēlēsiet datorspēli standarta apstākļos, Jums tiks veikti vairāki izmeklējumi 3 stundu garumā (ar 15 minūšu pārtraukumu ik pēc stundas):

- Jūsu roku ādas temperatūras mērīšana ar bezkontakta metodi, izmantojot speciālu termogrāfisku kameru, kura nosaka ķermeņa infrasarkanā starojuma intensitāti,
- roku muskuļu elektriskās aktivitātes noteikšana ar virsmas elektromiogrāfiju, kam būs nepieciešama elektrodu pielīmēšana uz apakšdelmu ādas,
- plaukstas ādas mitruma noteikšana ar speciālu sensoru,
- roku veiklības testi ar datorprogrammas palīdzību.

Lai mērījumi sanāktu precīzi, pirms izmeklēšanas nepieciešama Jūsu ķermeņa temperatūras nostabilizēšanās. Tādēļ pirms izmeklējuma Jums tiks palūgts novilkt no rokām traucējošus priekšmetus, atsegt roku ādu un 10-15 minūtes pastāvēt mierīgi (nedrīkst berzt vai kasīt ādu izmeklēšanai paredzētajā zonā – apakšdelmus un plaukstas).

Pirms pirmās testu dienas 1-2 dienas iepriekš būtu vēlams noskūt apmatojumu no apakšdelmiem (zemāk par elkoni), lai būtu iespējams pielīmēt elektrodus.

Sakarā ar to, ka ādas temperatūra var būtiski mainīties Jūsu uzvedības un dažādu faktoru dēļ, **izmeklējuma dienā nedrīkst**:

- lietot krēmu un kosmētiku izmeklējamai zonai;
- lietot alkoholiskos dzērienus un garastāvokli ietekmējošas vielas;
- dzert tēju vai kafiju vienu stundu pirms izmeklējuma;
- ēst vismaz stundu pirms izmeklējuma;
- dienu pirms un izmeklējuma dienā jāizvairās no piedalīšanās intensīvās fiziskās aktivitātēs;
- izmeklējuma dienā nevajadzētu lietot zāles, kas ietekmē sirds un asinsvadu sistēmu, kā arī nervu un muskuļu sistēmu;
- pirms izmeklējuma nevajadzētu apmeklēt jebkura veida fizioterapijas pasākumus un masāžu, pēc iespējas jāizvairās no jebkādas roku traumatizēšanas;
- nedrīkst smēķēt īsi pirms izmeklējuma.

Izmeklējuma dienā ieteicams uzvilkt brīvas un nenospiedošas drēbes ar īsām piedurknēm. Pārtraukumu laikā būs iespējams dzert istabas temperatūras ūdeni, bet nebūs iespējas paēst.

Testa dienā Jums nedrīkst būt drudzis vai saaukstēšanās. **Ja pastāv kādas veselības problēmas vai citi apstākļi, kas varētu ietekmēt mērījumu precizitāti, lūdzu, informējiet ārstu-pētnieku par tiem pirms izmeklējuma!**

Visi iegūtie uzņēmumi u dati tiks uzglabāti, ievērojot konfidencialitāti, un netiks publiskoti bez Jūsu piekrišanas. Jums ir tiesības izstāties no pētījuma jebkurā mirklī.

Rīga Stradiņš University
**INSTITUTE OF OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH**
Rātsupītes Street 5, Rīga, LV-1067, Latvia
Phone No. +371 67409139
E-mail: ddvvi@rsu.lv

Testus un izmeklējumus veiks Rīgas Stradiņa universitātes Darba drošības un vides veselības institūta pētnieki:

Vad. pētniece dr.med. Jeļena Reste mob. 26009303 ____________________________

Pētniece dr. Alise Guļājeva mob. 27119394 ______________________________

Norises vieta: RSU Darba drošības un vides veselības institūts, Rātsupītes ielā 5, Rīgā

Man ir izskaidrota pētījuma norise un es piekrītu piedalīties testos

Vārds, uzvārds__________________________________________
Paraksts_____________________________

Datums:_____________________________________