Analysis of the functional biomechanics of different chair types during eSports activity

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1 Introduction

The eSports community has grown rapidly in recent years. According to estimates, the number of active gamers only in Germany is 4.5 million players (Source: openPR.de) and Europe-wide at up to 22 million (Source: World Cyber Games). The hoped-for recognition of eSports as an independent sport by the German Olympic Sports Confederation as well as by the Federal Institute for Sports Science remains denied, in particular with the reference to a lack of motor activity. In fact, eSports is predominantly characterized by long-lasting, mostly motionless sitting and - in terms of motor activity - is limited to finger movements when operating input devices such as a keyboard, mouse or joystick.

Long periods of sitting, up to 10 hours per day of eSports, can be associated with poor posture, pain and damage to the biological structures involved (muscles, tendons and joints), e.g. due to shortened and slack muscles or undersupply of the cartilaginous disc structures. On the other hand, motionless sitting behavior is also responsible for the general muscular fatigue of large areas of the musculoskeletal system and thus has a direct influence on the performance when playing.

Fig. 1: Seating positions and chair types in eSports

The aim of the present study was therefore to identify load exposure to eSports-specific stress regions during the use of different chair types and to evaluate their significance for maintenance of functional flexibility (performance) as well as for protection of the musculoskeletal system.

Five male players of the eSports team of the German Sport University Cologne attended the three-part investigation. Firstly, they had the task of trying out four different chair types (three TOPSTAR, one NOBLE) while playing and then evaluating them based on a systematic and structured questionnaire. Second, computer-assisted 3D motion capture was performed on two players during the game to further assess and quantify the seating position and seating behavior in the four chairs. Third, a subjective disposition analysis was performed on the day of the study, also in the form of a systematic and structured questionnaire. The master data of the five subjects are shown in Table 1.

Master data of the participants (n = 5 ♂)	
Feature	**Mean ± SD**
age (years)	22 ± 2
height (cm)	190 ± 7
weight (kg)	89 ± 14
BMI (kg/m^2)	24 ± 3

Tab 1: Master data of the participants in means and standard deviations

3D motion capturing was used to record body position and possible body movements as well as to analyze the data regarding physical stress. The subjects were equipped with a whole-body inertial sensor system consisting of 17 so-called IMUs (Inertial Measurement Units) from *Neuron Perception* and calibrated using four defined body positions.

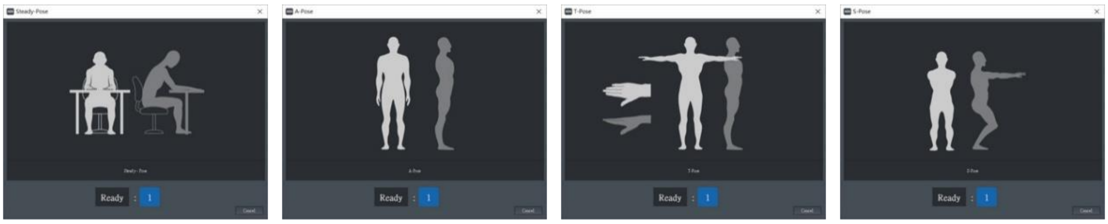


Fig. 2: Calibration of the inertial sensor system

The actual data acquisition when playing (League of Legends) on the various chair types was carried out with a measurement frequency of 120 frames per second. To evaluate the load characteristics, the measured data were then streamed and analyzed using the *Neuron Monitor* evaluation routine based on Unity-3D (see Fig. 3).

a) b)

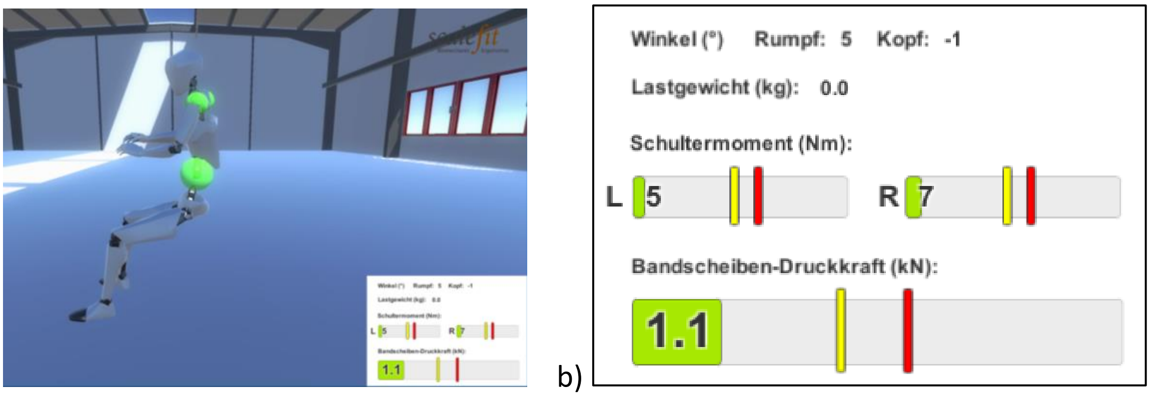


Fig. 3: a) Evaluation monitor and b) evaluation routine (enlarged) in Unity-3D

2 Results

2.1 Sensitivity analysis (questionnaire)

Based on a structured and systematic questionnaire, three aspects of the subjective condition were analyzed in the five study participants. The first part showed a pronounced e-Sports activity of 6.5 hours a day for 6.8 years, meaning that the gamer had been active in eSports since the age of 15 (see Table 2). The eSports activity contrasted with an exceptionally high physical activity of 1.3 hours per day (9.3 hrs. / week), which, however, was causally linked to the fact that all participants are enrolled sports sciences students at the German Sport University at the time of the data acquisition.

(e)Sports activity (n = 5 ♂)	
Feature	**Mean $\pm$ SD**
eSports experience (years)	6,8 $\pm$ 2,6
eSports playing time (hrs./day)	6,5 $\pm$ 5,1
eSports competitions (no./year)	7,2 $\pm$ 2,7
physical sports (hrs./week)	9,3 $\pm$ 4,3

Tab. 2: Overview of eSports and physical activities

In the second part of the survey (see Table 3), three out of five subjects stated that they were currently suffering from musculo-skeletal complaints in the area of the cervical and lumbar spine as well as the shoulders. Two of them were therefore receiving medical treatment.

(e)Sports activity (n = 5 ♂)	
Feature	**Result**
current complaints (n)	3
under med. treatment (n)	2
complaint areas	cervical & lumbar spine, shoulder

Tab. 3: Overview of musculo-skeletal complaints

In the third part, the subjects gave information about their seating behavior during eSports activity (see Tab. 4). Three out of five players used a special game chair and two out of five players used an office chair. When sitting, the front and rear seating position were preferred (two resp. three players), which was rarely changed in all subjects. According to all the players, the most important adjustment options for the chair types were the height of the seat and armrest as well as the tilt adjustment of the backrest. No use was found for stools and the rear seat position.

Sitting behavior (n = 5 ♂)	
Feature	**Result**
using game chair | office chair | stool	3 | 2 | 0
front | center | rear seat position	2 | 3 | 0
seat position change often | rare | never	0 | 5 | 0
important adjustabilities (100% nomination): a) seat height b) height armrest c) tilt backrest	

Tab. 4: Overview of seating behavior at eSports

2.2 Assessment of chair types (questionnaire)

On the day of the examination, subjects were confronted with four different chair types. Their task was to use all chairs during an eSports activity until a final assessment was possible (see Table 5). The following questions should be answered according to a grading system (1 = very good, 2 = good, 3 = medium, 4 = bad, 5 = very bad):

How do you assess ...

- adjustment of seat and backrest
- comfort / ergonomic design (pressure distribution, shape, material)
- support of the musculoskeletal system through the chair
- functionality of the chair (when playing)?

eSports chair types – subjective rating (n = 5 ♂)					
	adjustability	comfort/ ergon. design.	support	functionality	TOTAL
TOPSTAR game chair (TG)	1.0	1.2	1.2	1.8	**1.3**
NOBLE game chair (NG)	1.4	1.4	1.4	1.6	**1.5**
TOPSTAR office chair (TO)	4.2	4.4	4.4	4.0	**4.3**
TOPSTAR stool (TS)	2.4	2.4	3.2	3.2	**2.8**

Tab. 5: Subjective assessment of the examined chair types

For the categories *adjustment, comfort / ergonomic design* and *support*, the evaluation of the 20 questionnaires showed best scores for the TOPSTAR game chair (1.0 to 1.2) followed by the NOBLE game chair (all 1.4). However, the NOBLE scored the highest rating in the *functionality* category with a score of 1.6. In the overall ranking the TG was the only chair with the highest grade (*very good*), followed by the NG (*good*), the TOPSTAR stool (*medium*) and the office chair (*bad*). For the stool, the evaluation of musculoskeletal support and functionality had a negative impact on the overall result. The office chair was rated *bad* in all categories.

2.3 3D-Motion Capture

By using the *Neuron Perception* motion analysis system, eSports-specific load parameters were recorded three-dimensionally during play. Two players, wearing the portable measuring system, played the multiplayer game *League of Legends* on four chair types for two to four minutes. After an individual warm-up period, which was defined until the establishment of a stable sitting and playing position, the load parameters were recorded using the *Neuron Monitor* evaluation routine. From the results of both subjects, the mean value was calculated and used for further evaluation (see Tab. 6).

Load exposure by chair types (n = 2 ♂)					
	trunk angle (°)	head angle (°)	shoulder moment left (Nm)	shoulder moment right (Nm)	intervertebral disc pressure (kN)
TOPSTAR game chair (TG)	2	8	3	5	0,95
NOBLE game chair (NG)	7,5	7	3,5	4,5	1,25
TOPSTAR office chair (TO)	3	6,5	3	4	0,95
TOPSTAR stool (TS)	8	12	4	5	1,3

Tab. 6: Load parameters for eSports on different chair types

As a load parameter, the *trunk angle* describes the inclination of the trunk and thus has a decisive influence on the static spine load. This angle is essentially influenced by the geometry of the backrest of the respective chair, that means a stronger trunk inclination forced by the backrest correlates with a higher back load. NG and TS (7.5° resp. 8°) generate high values while TG and TO (2° resp. 3°) are low and thus less stressful.

The direct comparison between NG and TG shows significant differences in the design of the backrest contour. NG has a concave half-shell shape, which dispenses with the support of the lumbar lordosis and thus seems to force the entire course of the spine into a nonphysiologically round shape (see red line in Fig. 4a). In contrast, the anatomically shaped backrest of the thoracic and especially spinal column offers functional support of the postural system (see green line in Fig. 4b) and also allows an upright, reduced-stress sitting position.

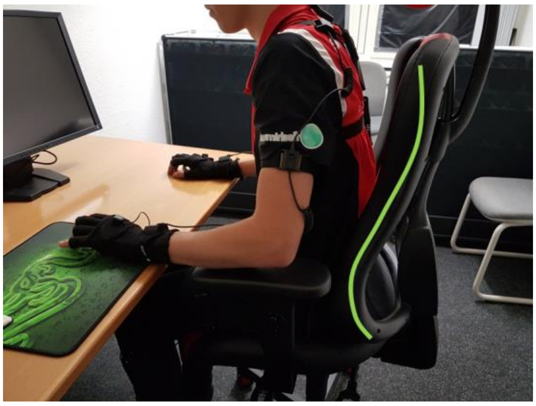
a)  b) 

Fig. 4: a) Concave NOBLE backrest and b) anatomical TOPSTAR backrest

Regarding the head angle, it is noticeable that the stool use causes an increased head adjustment value (12°) while the use of the three chair variants produces comparable setting values at a low level (6.5° to 8°). However, corresponding to the ISO standard 11226, which is responsible for ergonomics and postures, both adjustment ranges lie within the range of movement of the head defined as non-stressful (0° to 25°).

The external shoulder moments, which are calculated from the segment masses (upper arm, forearm, hand) and their respective distance to the shoulder center point, do not reach any load-relevant magnitudes or limit values (3 Nm to 5 Nm). In addition, since the forearms are placed on the table while playing and thus the shoulders are additionally relieved, the shoulder moment can be excluded as an eSports-typical load parameter.

When looking at eSports-induced musculoskeletal loads, back strain with the associated disc pressure is certainly crucial. In the pathologically most interesting area, the lumbar spine, the intervertebral disc pressure force is generated on the one hand from all externally acting moments (mass of the head, trunk, arms and hands and the corresponding lever arms) and on the other hand from the muscular strength of the back-extensor muscles with their corresponding muscular lever arms. At the same time, the force of the back extensors attaching to the spinous processes of the vertebral bodies also causes a compression of the spinal column as well as of the interposed intervertebral discs. In biomechanics, this compressive force is referred to as intervertebral disc pressure (IDP).

Compared to standing (0.8 kN), the IDP shows only slightly elevated levels (0.95 kN) when sitting in the chair types TG and TO, which should show only low structural damage in short to moderately long exposure times (max. 4 hours/day). In contrast, sitting for NG (1.25 kN) and TS (1.3 kN) causes a significant increase (approximately 30%) in the compression force acting on the disc cartilage. An increased load, especially in combination with long exposure times of up to 10 hours daily, already poses an intermediate to high risk of supply deficits and degenerative damage to the involved cartilaginous and bony structures (see Fig. 5).

Fig. 5: Degeneration of the intervertebral discs and vertebral bodies by long sitting

3 Discussion and summary

With regard to the different chairs, the results of the investigations showed clear differences between objective load data (motion capture and biomechanical modeling) and subjective assessments (questionnaire). The biomechanical analysis showed low mechanical stress on the musculoskeletal system when using the TOPSTAR game chair and the TOPSTAR office chair. By contrast, when playing on the NOBLE game chair and the TOPSTAR stool, the compression load increased by up to 30% and even reached the area of increased damage potential.

The subjective rating showed similarly good results for the TOPSTAR game chair (top score in 3 out of 4 sections, overall score: *very good*) but not for the TOPSTAR office chair (overall score: *poor*). On the other hand, with the overall score *good* and the top grade in 1 of 4 sections, the NOBLE game chair was able to keep up with the winner in this area.

The design of the backrest could be identified as an essential difference between the chair types used and as a possible cause of the varying feature characteristics. The TOPSTAR game chair has an "open" backrest shape, similar to the office chair, which, thanks to its anatomical shape and reduced side borders, allows an ergonomically favorable, upright posture and lateral movements of the upper body. This avoids additional forced posture of the trunk, which is associated with increased disc compression. On the other hand, micro-movements are made possible, which counteract deficiency of the intervertebral discs and muscular fatigue. The best scores for comfort / ergonomic design and musculoskeletal support of the subjective survey, support these assumptions.

In contrast, with its concave backrest and lateral boundaries the NOBLE game chair shows a more "closed" shape, which brings the upper body into a bent position and stabilizes laterally. This performance-oriented backrest may aim to focus the gamer on the game, which is also supported by the top score for *chair functionality*. However, no functional aspects for the prevention of musculoskeletal disorders, for example by allowing lateral body movements, can be recognized for this chair.

During physical activity either at work or leisure time, health protection and maintenance of physical and mental capacity must be prioritized. When sitting for long periods, as occurs on VDU workstations but especially during eSports, the body experiences a partial, monotonous and supply-reducing mechanical load. It has been proven that this causes degenerative changes in the musculoskeletal system, especially in the intervertebral discs. Among the study participants who received medical treatment for their complaints, the thoracic and lumbar spine were particularly affected.

The present research shows that the use of "open" backrest-style game-chairs, as in the TOPSTAR Sitness Racer, can reduce physical stress and thus prevent fatigue, pain and damage. A chair that allows movements can thus influence the long-term maintenance of motor performance and fitness as well as physical health. However, this behavioral prevention should not be the only approach to counteract the effects of sitting, as the most effective way to avoid physical degeneration remains physical activity. Therefore active breaks and (health) sports must find their way into eSports to provide a compensation that even the most innovative chair cannot offer.