Testing e-sport athletes

A study on competitive gaming

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THE SWEDISH SCHOOL OF SPORTS
AND HEALTH SCIENCES

Bachelor degree project 157:2013

Sports science: 2011-2014

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Aim

The main purpose of this study was to compose and test the validity of a cognitive test battery to determine e-sport athletes' strengths and weaknesses. The second purpose was to investigate their physical fitness. Hypothesis 1: The elite players will perform better in a number of cognitive and fine motor tasks compared to recreational gamers. Hypothesis 2: The elite players' aerobic capacity cannot be very low (<2,5 VO_2 L/min for 20-29 year olds) according to Andersson since that would affect their e-sport performance negatively. Hypothesis 3: A great number of the elite players will not be able to match the demands (>198 seconds) for a healthy back in the Biering-Sørensen test.

Method

25 male test subjects were divided into three groups, elite players (E) [10], recreational players (R) [10] and non-players (N) [5]. The elite group consisted of two professional e-sport teams á five persons, one Counter Strike: Global Offensive-team (CS) and one League of Legends-team (LOL), ranging between 17 and 25 years of age (mean age 21,5). R ranged between 21 and 29 years of age (mean 24,9) had all played fighting games, MOBA, online-FPS, online-3PS or RTS games minimum once a week in a 6 month period or more but never competed in them. N ranged between 25 and 32 (mean 28, 4) years of age and had at a maximum tried these kinds of games but never used them for recreational purposes.

E, R and N performed a test battery for reaction speed, strategy, perception, situation awareness, keyboard stamina, hand-eye coordination, spatial orientation and anticipatory skill. E was also tested for physical fitness through Ekblom-Bak submaximal cycle ergometer test and back strength with Biering-Sørensens (BS) test.

Results

E estimated VO_2max was 3,83 L/min (SD = 0,38) and E's mean result from BS back test was 133 s (SD = 54). The elite players did not perform significantly better in any of the cognitive or fine motor task than the recreational players.

Conclusion

The elite player's results from the BS test confirms hypothesis 3 and indicates unhealthy backs. The only significant difference within the cognitive tests between E and R is to the E groups disadvantage; surprisingly they showed inferior results in the anticipatory skill test. Their aerobic capacity confirms hypothesis 2, the elite players VO_2max was not very low, placing the E group in the upper half of the average in their age group. Furthermore, the test battery cannot be used for talent scouting but could possibly be used to determine cognitive weaknesses.

Syfte

Huvudsyftet med denna studie var att sammansätta och testa validiteten i ett kognitivt testbatteri för att bestämma e-sportatleters styrkor och svagheter. Det andra syftet var att undersöka deras fysiska status.

Hypotes1: Elitspelarna kommer att prestera bättre i en rad kognitiva och finmotoriska uppgifter jämfört med rekreationsspelare. Hypotes 2: Elitspelarnas aeroba kapacitet kan inte vara mycket låg (<2,5 VO_2 L/min för 20-29åringar) eftersom det skulle påverka deras e–sportprestation negativt. Hypotes 3: Ett stort antal av elitspelarna kommer inte att kunna matcha kraven för en frisk rygg (>193 sekunder) i Biering-Sørensentestet.

Metod

25 män delades in i tre grupper, elitspelare (E) [10], rekreationsspelare (R) [10] och icke-spelare (N) [5]. Elitgruppen bestod av två professionella e-sportslag á fem personer och ett Counter Strike: Global Offensivelag (CS) och ett League of Legends-lag (LOL), ålder mellan 17 och 25 år (medelålder 21,5). R-gruppen varierade mellan 21 och 29 år (medelvärde 24,9) hade alla spelat fightingspel, MOBA, online-FPS, online-3PS eller RTS-spel minst en gång i veckan under en 6 månaders period eller mer men aldrig tävlat i dem. Grupp N varierade mellan 25 och 32 år (medel 28,4) och hade som högst provat dessa typer av spel, men aldrig använt dem i rekreationssyfte.

Grupp E, R och N utförde ett testbatteri för reaktionshastighet, strategi, perception, situationsmedvetenhet , tangentbord uthållighet, öga-handkoordination, spatial förmåga och antecipatorisk skicklighet. Grupp E också testades fysiskt genom Ekblom-Bak submaximala cycle ergometertest och ryggstyrka genom Biering-Sørensens (BS) test.

Resultat

Grupp E:s beräknade VO_2max var 3,83 l/min (SD = 0,38) och elitgruppens medelresultat av BS ryggtest var 133 s (SD=54). E presterade inte signifikant bättre i någon av de kognitiva eller finmotoriska uppgifterna än R.

Slutsats

Elitspelarnas resultat från BS-testet bekräftar hypotes 3 och påvisar ohälsosamma ryggar. Den enda signifikanta skillnaden inom de kognitiva testerna mellan E och R är till E-gruppens nackdel, överraskande visade de sämre resultat i det antecipatoriska skicklighetstestet . Deras aeroba kapacitet bekräftar hypotes 2, elitspelarnas VO_2max var inte mycket låg, E-gruppen placerade sig i den övre hälften av genomsnittet för sin åldersgrupp. Testbatteriet kan inte användas för talangscouting men eventuellt för att upptäcka kognitiva svagheter.

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1. Introduction

Competitive computer gaming, now known as the Korean made expression *e-sports*, short for electronic sports. This has become increasingly important in terms of events and audiences, and likewise also started taking more and more space in everyday media - as part of the public service channels, both radio and television. It is worth mentioning that in a recent World Cup in one of the games, Defense of the Ancients 2 (DOTA2) which is a team sport, the five Swedish winners went home with 1.4 million dollars. Also important to note is that the second- and third place finishers did not leave completely empty-handed. In other words, there is a lot of prize money in the sport, although this was the largest price so far, other e-sportsevents shows the same trend.

Two important points to from the above, Sweden is a world leader in at least one of the branches and e-sports is starting to involve a lot of money. For those that have not been introduced to it, e-sport might be perceived as a brief fad since it came very quickly and "out of nowhere". Although e-sports is a brand new phenomenon in a sports context, its' origin is dating from the late 1990's where Korea in the game StarCraft had a professional league with professional teams and everything related to it - it was during this time e-sports as an expression and a recognized competing phenomenon emerged.

E-sport today involves several different games, both on computers and gaming consoles. And in 2008 International e-Sports Federation (IeSF) was founded, that provides world championships, world rankings and standardization, as stated on their webpage:

> *"International e-Sport Federation consistently makes an effort to promote e-Sport as a true sport beyond language, race and culture barriers, As our fulfillment of past years, we produced meaningful and tangible results by hosting annual 'IeSF World Championship' and 'General Meeting', and we have expanded our member nations beginning from 9 to 42 nations. Furthermore, we presented a global standard for e-Sports integrated development of each country by instituting 'international e-Sports standardization'".*
>
> (IeSF 2013)

In this study competitive gaming involves games under the following branches, categorized after game mechanics using the standard game industry categories:

Real time strategy (RTS) games are being viewed from an isometric perspective. In this type of games usually two players would meet controlling their own army. The game play involves building and expanding your base, managing your resources, and battling your opponents' army. This would be where StarCraft (SC) would fit.

The following two categories could be considered subcategories to RTS with the mechanics in mind. Multiplayer Online Battle Arena (MOBA) and FIFA – which would be refereeing to the international football association.

MOBA games originates from RTS which makes it a natural subcategory, now the genre has grown enough to make an own branch. The variation MOBA is a team game were two teams consisting of five players meet, all being viewed from an isometric perspective. Each player controls one unit, sometimes with appendage, and together with the team the objective is to dominate the arena and coordinate attacks to defeat the opposing team. Well know titles within this category would be League of Legends (LOL) and DOTA2.

The football games, with the FIFA-series being the most common in competitive context, are also viewed from an isometric perspective – which is one of the reasons for classifying it as an RTS subcategory. Ordinarily two players meet controlling their own team with the goal to outscore their antagonist, all within the general practice and regulations of football. Which states the other reason for subcategorizing it as RTS; players' are controlling the whole team with an overview of the game.

Furthermore other large categories would be First- or 3rd person shooters (FPS & 3PS) and fighting games which differs quite a bit regarding to mechanics in comparison to RTS and its' subcategories.

First- or 3rd person shooters (FPS & 3PS) are games were you control a soldier a first person perspective, or just behind – third person view. Either it is free for all or teams face each other; even though there can be different missions (e.g. capture the flag or defend a certain area) where the task can vary a great deal, the mechanics is to discover the opponents and shoot them. Counter Strike: Global Offensive (CS) is now being the largest FPS-game but there are several other games in which people compete.

Fighting games; usually involve two players opposing each other from a third person perspective in a sagittal view. Through different button combinations perform various attacks against each other with the goal being to beat the adversary. Well known games within this genre would be the Tekken-series and Street Fighter-series.

Even though the sport has become very large - none, or very little, research has been done about performance within e-sports. This study will refer to several studies showing that individuals will improve in many aspects as a consequence of video gaming and also research showing that there are important aspects of the game play. These aspects will be categories as following under *previous studies*. There is also research showing that higher level of physical fitness correlates with improved cognitive functions (Haappala 2013; McKee, Daneshvar, Alvarez & Stein 2014; Luque-Casado, Zabala, Morales, Mateo-March & Sanabria 2013; Lorås, Stensdotter, Öberg & Sigmundsson 2013), but exercising is not yet considered to be a complement to the e-sport specific training.

As mentioned, little is scientifically researched about the demands, cognitive as well as physical, for e-sport professionals. To open up for this kind of research, there needs to be some grounding work done, establishing what test procedures can be used in order to make demand profiles which this study intend to do.

1.1 Previous studies

The aim of the study was to test what decisive parameters that makes an e-sport athlete on a professional level. Though there has not been any quantitative research made on e-sports, studies on video game players sums up what cognitive demands is put on the players.

> *"The need for fast and efficient selection when playing video games is particularly great, because video games typically involve demanding visual input that requires fast hand–eye coordination, quick reflexes, and precision timing. It is crucial for successful video game performance that players rapidly select relevant information and ignore irrelevant information. "*
> (Chisholm, Hickey, Theeuwes & Kingston 2010)

This list of demands is also confirmed by Appelbaum three years later, with an extension of abilities.

”Action video game playing has been experimentally linked to a number of perceptual and cognitive improvements. These benefits are captured through a wide range of psychometric tasks and have led to the proposition that action video game experience may promote the ability to extract statistical evidence from sensory stimuli. Such advantage could arise from a number of possible mechanisms: improvements in visual sensitivity, enhancements in the capacity or duration for which information is retained in visual memory, or higher-level strategic use of information for decision making.”
(Applebaum, Cain, Darling & Mitroff 2013)

The oldest relevant research found made on video game players was on the perspective of eye-hand coordination, suggesting that the results to the players superior skills in the study was not because of playing video games, but that individuals with already good eye-hand coordination choose to play video games (Griffith, Voloschin, Gibb & Bailey 1983). However recent research has even tried to examine what cognitive functions are used when improving the performance within a specific video game (Boot, Basak, Erickson, Neider, Daniel, Simons, Fabiani, Gratton, Voss, Prakash, Lee, Low & Kramer, 2010, Tippett & Rizkalla 2013).
Below is a classification of the capacities selected for this study, based on the previous research mentioned above.

Reaction Speed

Although not proven, reaction speed plays a large role in video games both according to scientists (Chisholm et al. 2010) and the performers themselves (Denkert & Friberg 2011). There is reason to classify e-sports as an open-skill sport (McBride & Rothstein 1979) which according to Wang, Chang, Liang, Shih, Chiu, Tseng, Hung, Tzeng, Muggleton, & Juan (2013) correlates with superior inhibitory control. Though only volleyball players and sprinters was compared, this study (Nuri, Shadmehr, Ghotbi, & Mogadam 2013) suggests that visual reaction speed does not alter between open and closed skill sports. Newcorn, Halperin, Jensen, Abikoff, Arnold, Cantwell, Conners, Elliott, Epstein, Greenhill, Hechtman, Hinshaw, Hoza, Kraemer, Pelham, Severe, Swanson, Wells, Wigal, & Vitiello (2001) constructed a

Go/NoGo task where the participants were to react on only certain visual stimuli. The reliability estimates for the Go/NoGo test is considered to be moderate to high (Weafer, Baggott, de Wit, 2013) and it has been selected to test reaction speed for this study.

Strategy

The game genre real-time strategy indubitably signals that strategic sense would be a making marker for success. Strategy video games may promote an increase in careful planning and executive control of behavior (Basak, Boot,Voss, Kramer 2010 see Bailey, West & Kuffel 2013 p. 2). To test the participants' success in calculating risks, the *Iowa Gambling Task* (IGT) (Bechara, Damasio, Tranel & Damasio 1997) is a well used test. A study made on video game addicts shows that FPS-players has higher risk taking in the Iowa Gambling Task than strategy players (Bailey, West & Kuffel 2013). Other studies on sports also correlates low net scores with disadvantaged decision (Lage, Gallo, Cassiano, Lobo, Vieira, Salgado, Fuentes & Malloy-diniz 2011). Another spectra of the tactics, is the the players planning, which was studied through the *Tower-Of-London* (TOL) task (Shallice 1982), a task originally designed to test patients with lesions of the frontal lobe, but is still being used for many other purposes, chess players has outperformed non-chess players with fewer moves to solve the tasks (Unterrainer, Kaller, Leonhart & Rahm 2011).

A reliability study shows that individual trial time was constant over sessions (Lemoy, Bedard, Roleau & Trembley, 2010). Both the pebl-versions of IGT and TOL have been used in peer reviewed research (Newman 2009).

Perception

Very recently Appelbaum et al. (2013) published a study showing that action-, FPS- and platform videogame players were able to react to smaller visual changes than non video game players. Mueller (2010) designed two tests, a classic *visual search* and a *change detection* test, (Fencik, Seymour, Mueller Kieras, and Meyer 2002) based on the paradigm that with shorter reaction time, accuracy is lost (Pashler 1998, s. 16). These were selected in this study to determine the participants' perceptual ability.

Situation Awareness

Situation awareness is a major concern in video games according to Chisholm, Hickey, Theeuwes, Kingstone (2010) who shows that video game players perform better with attention based tasks. They theorize that this can be due to the capacity to ignore distracting factors. The PEBL program has a novel designed s*ituation awareness*-test that tests different tasks one by one and then mixes them up – giving a possibility to measure the decrease in performance when having to focus on many factors at once compared to only one and was therefore selected in this study.

Actions per minute

In StarCraft 2 one action in this context is a click on the mouse button or a keyboard button. There has been a lot of talk of actions per minute (APM) (Denkert, Friberg 2011) though no research was found to indicate that it is an actual perimeter of performance, however it is considered to be a metric used to judge a players skill (Cheung & Huang 2011). The method selected for testing the keyboard stamina was to record the number of keyboard taps the participant could do in one minute. This was to be done with the left hand to make it e-sport specific since the athletes has the right hand on the mouse.

Hand-eye coordination

Research found within this area is concurrent. The old study from Griffith, Voloschin, Gibb & Bailey (1983) studied video-game users versus non users, letting them follow a rotating red dot with a mouse cursor, with a superior result for the video game users. In more recent studies, Borecki L, Tolstych K, Pokorski M (2013) compared Counter-strike players and non-video game players in seven fine motor skill tasks, resulting in significant better results for the counter strike players in all seven tasks. Middleton, Hamilton, Tsai, Middleton, Falcone & Hamad (2013) showed that accuracy on an eye-hand coordination task was significantly improved from playing Nintendo Wii. For this study, two tests were selected for this capacity, one being a novel design manual dexterity test from PEBL (Mueller 2010) and the other one being the *pursuit rotor* (PR) task used by Griffith, Voloschin, Gibb & Bailey (1983) remade for the PEBL software, which also has been used in peer reviewed research (Piper 2011).

Spatial Orientation

There are common computer games that more or less are built on the players' ability for fast mental rotation, the most classic one of these games being "Tetris". These games have shown to increase the players skill for mental rotation (de Lisi & Wolford, 2002) by letting the subjects be presented with two matrices side by side and decide whether the matrices are identical, except that one is rotated, or actually two different structures. These previously mentioned games are not represented within e-sports hence the question is if also computer games whose major game mechanics not consists of mental rotation also improve this ability, since orientation still plays an important role, within i.e. reading the map. The test used by Lisi & Wolford (2002) was perceived as hard to explain and therefore too time consuming to include in the test battery, instead a similar *matrix rotation* (MR) test (Englund, Reeves, Shingledecker, Thorn, Wilson & Hegge 1987) was selected with the main difference being that instead of seeing two matrixes presented at the same time they are presented after each other.

Anticipatory skill

Chisholm, Theeuwes and Kingstone (2010) also mention precision timing as a demand for playing video games and no doubt that the ruling paradigm and according to Nuri et al. (2013) were open skill athletes superior to closed skill in anticipatory skill. Also fetched from the U.S. Navy test battery (Englund et al. 1987) a "*time wall*" (TW) task was selected, a task where the participants were to estimate when a dropping square hits the target without seeing the objects last part of the fall – in later research also used via PEBL (Piper, Li, Eiwaz, Kobel, Benice, Chu, Olsen, Rice, Gray, Mueller, Raber 2012). This task is in spirit the very same as the description for the test used by Nuri et al. (2013).

Physical Fitness

There is reason to believe that e-sport athletes are exposed to a high risk of upper body musculoskeletal disorders if combined with bad posture, since professional gaming is a desktop job with long working hours (Epstein, Colford, Epstein, Loye, Walsh 2012, d'Errico,

Caputo, Falcone, Fubini, Gilardi, Mamo, Migliardi, Quarta & Coffano 2010) and that this could be treated through physical work-out (Manniche, Hesselsøe, Bentzen, Christensen, Lundberg 1988, Johnsson & Nachemson 2000, Hayden 2012, Hansson 2008).

Further research correlates fitness levels with superior cognitive performance and motor skills in various age categories (Haapala 2013; McKee et al. 2014; Luque-Casado et al. 2013; Lorås et al. 2013) and research on young polish national team chess players shows that their fitness levels were satisfactory to age matched control (Fornal-Urban, Keska, Dobosz, Nowacka-Dobosz 2009). Also worth mentioning is that research shows no negative effects on fine motor skills after strength training (Smits-Engelsman, Smits, Oomen, Duysens 2007).

For this study two areas were selected for testing, the static back strength and aerobic capacity. Endurance of the back extensor muscles measured using the Biering-Sørensen test which was designed to investigate lower back trouble and compare the E participants results to the ones in the Biering-Sørensen (1984) study. Maximal oxygen uptake (VO_2max) was tested since it is considered as an independent predictor of cardiovascular health (Powell & Blair, 1994). VO_2max was estimated through the Ekblom-Bak submaximal test since it has showed higher precision than the previously most commonly used test for the purpose; Åstrand test (Ekblom-Bak, Björkman, Hellenius & Ekblom 2012). The results was compared to the average VO_2 metrics for their age group as plotted out by Andersson (2010, p.37) in the categories *very low, low, average, high, very high* and *elite*.

1.2 Aim

The purpose of the study was to develop and test the validity of test methods to determine e-sport athletes' strengths, weaknesses and potential use for talent scouting. The purpose was also to investigate their physical fitness.

1.3 Hypothesis

Hypothesis 1: The elite players will perform better in a number of cognitive and fine motor tasks compared to recreational gamers

Hypothesis 2: The elite players' aerobic capacity cannot be very low according to Andersson, 2010, since that would affect their e-sport performance negatively.

Hypothesis 3. A great number of the elite players will not be able to match the strength demands for a healthy back according to Biering-Sørenssen.

2. Methods

2.1 Participants

8 of the most successful Swedish elite e-sport teams was contacted via e-mail, 4 responded but two later cancelled their participation. R and N participants were sought for at the Swedish school of sports and health sciences in Stockholm, via a mass e-mail through the schools internal mailing system.

25 males, aged 17-32 (mean 24), all right-handed and none colorblind, were informed of the study's purpose and methods and their identities were not made official, in line with the work of the ERC's principles (National advisory board on research ethics 2009, pp. 2-17). The participants were given the opportunity to ask questions and got them answered truthfully.

25 test subjects were divided into three groups, elite players (E) [10], recreational players (R) [10] and non-players (N) [5]. The elite group consisted of two professional e-sport teams á five persons, one CS:GO-team(CS) and one LOL-team, ranging between 17 and 25 years of age (mean age 21,5). The R group ranged between 21 and 29 years of age (mean 24,9) had all played fighting games, MOBA, online-FPS, online-3PS or RTS games minimum once a week in a six-month period or more but never competed in them. The N group ranged between 25 and 32 (mean 28, 4) years of age and had at a maximum tried these kinds of games but never used them for recreational purposes. The participant selection was made to match the elite group in sex and age, though the latter mentioned was hard to find males participants in similar age.

Exclusion

A total of eight women had to be excluded from the test. At first women was a part of the three different groups, but because of sickness within the elite groups' female players, the

number could not be matched throughout the different test groups. Also two male elite players dropped out of the test.

2.2 Apparatus

By digitally test a collection of tests, described in the execution part below, Psychological Experiment Building Language (PEBL) (Mueller 2010) software was used. The hardware consisted of two HP EliteBook laptop computers, with a 4 GB RAM memory and 2,70 GHz i7 CPU. The mouse was a Fuijitsu Blue Led Mouse GL9000 on a Steel Series QCK 320x270mm mouse pad, with 1000 dpi and windows sensitivity 6/11.

For the Ekblom-Bak (2012) test, 828e Ergomedic test bike was used; heart rate (HR) was registered with Polar FT1 heart rate monitor.

2.3 Execution:

The tests was performed between 9:00 and 16:00 in the laboratory of applied sports science at the Swedish school of sport and health sciences in Stockholm.

Cognitive tests

The PEBL version 0.13 software (Mueller 2010) was used with the test battery version 0.8's scripts; each individual test is called script. The following 11 tests carried out within 50-70 minutes, were used as a test battery for the study, in the order stated below and show in figure 1:

Change detection test: Script "changedetection.pbl" used. The participants were to watch the screen which altered between two almost identical pictures showing dots in different colors and sizes; the one difference meant one dot that changed position, color or size. The show time of the pictures is 400 ms and between them there is a black screen which is shown in 100 ms. Accuracy and response time was recorded during the first two minutes of the test. The participants was told to perform the task as fast and as accurate as possible.

Manual Dexterity: Script "dexterity.pbl" used. The noise conditions within the script were altered from "noiseCond <- [1,3,5,7,9,12,15,20]" to "noiseCond <-

[10,15,20,25,30,35,40,45]". This meant increasing the noise. Accuracy, amount of trials and direction changes was recorded during two minutes, and then the test was aborted.

Go/no-go test: Script "gonogo.pbl" used. The first round contained the task of avoidance of the letter *R* and reaction on the letter *P* within four covered windows. The letter would appear in one of the windows. The second round of the test with the inverted task, avoid *P* and react on *R*, was not used. The script was not altered, although a manual shut down of the script before the start of the second round was needed.

Iowa Gambling Task: Script "script iowa.pbl" used. The participants were given verbal instructions that some of the decks were better than the other decks, and when they figure out which, they should go for them, and thereby maximize their net score or more importantly at least repay the 2000 $ that was their starting capital.

Matrix Rotation: Script "matrixrotation.pbl" used. The participants were shown a pattern in a 6x6 squared field, which were to be memorized before continuing. The following depiction of the pattern is either rotated 90 degrees left or right, or a different pattern is shown. The task was to distinguish whether it was the same pattern or a new one. The participants were told to perform the task as fast and as accurate as possible.

Pursuit Rotor: Script "pursuitrotor.pbl" used. The radius of the dot was altered from 25 units to 15 units. The task included following a dot moving around a marked circular orbit with the cursor. The participants had four trials, and each trail lasted 15 seconds. From which the mean value was extracted.

Keyboard stamina: Script "timetap.pbl" used. The participants were asked to tap the A-key with the left hand as many times as possible for 1 minute. The participants had three trials, average and top notation was extracted.

Time wall: Script "timewall.pbl" used. The participants were to estimate when a falling object would hit a mark. The participants could see the falling object until the bottom third of the screen, and the mark was placed at the bottom of the screen. The trajectory of the object was fixed though the speed altered between the 20 trails. Two areas was measured – the participants inaccuracy and whether the average estimation was too long, too short or if equally many hits was made before and after the mark.

Tower Of London: Script “tol.pbl” used. Protocol chosen: “Unconstrained pile heights, {3,4,5} disks, progressive difficulty, 24 trials”. By counting the moves and time to solve the puzzles, the Tower of London exercise has been used for testing *problem solving* skills. The participants were told to perform the task as fast and as efficient as possible.

Situation awareness: Script “satest.pbl” used. The participants were to look at the computer screen and survey 5 animals moving around. After a period of time the animals disappear simultaneously from the screen. After that there were three different tasks; Task 1: After the disappearance of the animals the participants were asked to plot out their positions on the screen at the moment of disappearance. The script extracts results in inches, though in this study the term is exchanged to *units* since the inches is depending of the screen size. Task2: After the disappearance of the animals, a circle was placed at the position of the screen were one of the animals was. The participants’ task was to decide which of the animals were in this position. After doing so a second circle appeared with the same purpose. Task 3: After the disappearance of the animals, a dot was presented at the position of one of the animals. The task was to point out the direction of which that animal was moving.

Every task was first performed five times after each other. After that, they were performed once again but now in randomized order, meaning the participants had to be aware of all three aspects at the same time. The test is a novel design according to the PEBL webpage (Mueller, S.T. 2010), and the test used is not altered from the original except for the amount of trials. The trail conditions within the script were altered from “trials <- [3,3,3,15,15,15]” to “trials <- [2,2,2,5,5,5]”. This meant decreasing the amount of trials as mentioned earlier.

Visual Search: script “vsearch.pbl” used. The test was not altered, though the amount of trails was reduced to 30 instead of 180. This meant aborting the task during the already programmed break after 30 trials. The participants’ instructions were to find the target amidst clutter, a classic test translated into digital form. The task involved being shown a letter, “target”, for a short amount of time, which were followed by a field of mixed letters. The participants had to search the field as fast as possible for the target, and when finished searching having to click with the mouse. This meant the letters being covered with black circles, the subject were to click on a circle covering the target or press a “NONE” button at the top of the screen if the target was not shown during the search. The participants were told to perform the task as fast and as accurate as possible.

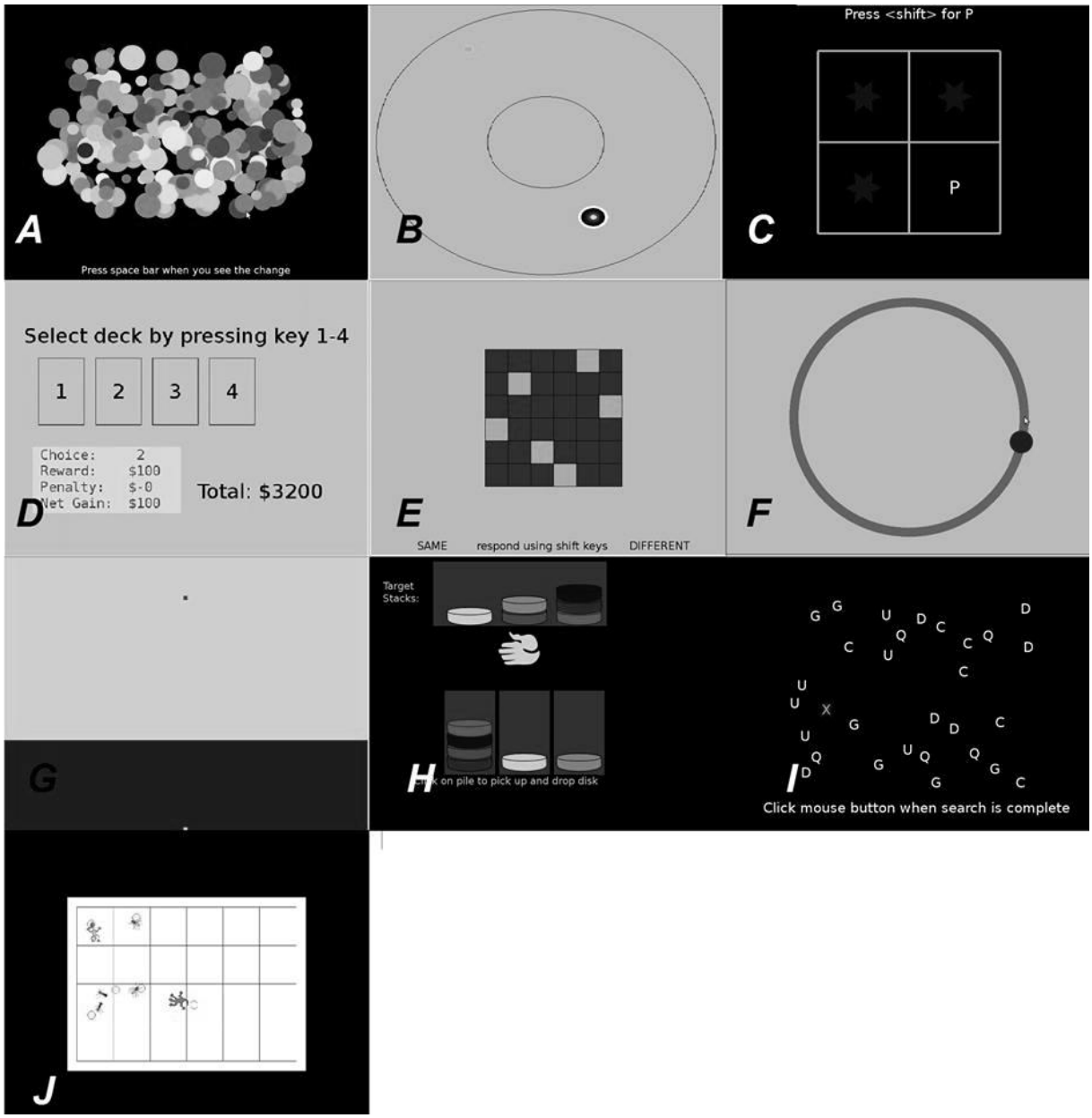

Figure 1: Screenshots from the all the cognitive tests except for the keyboard stamina test. a) Change detection, b) Manual dexterity, c) Go/no-go test, d) Iowa gambling task, e) Matrix rotation, f) Pursuit rotor, g) Time wall, h) Tower of London, i) Visual search, j) Situation awareness

2.4 Physical Fitness tests

Two physical health tests were used on the elite group. For the physical testing the aerobic capacity Ekblom-Bak submaximal cycle ergometer test were used to estimate their VO_2-max, and back strength through BS-test.

Ekblom-Bak

For the physical testing the aerobic capacity Ekblom-Bak submaximal bicycle test was used to estimate their maximal oxygen uptake, VO_2-max. The standard protocol for testing with Ekblom-Bak (Ekblom & Ekblom-Bak 2012) along with the standardized equipment was used. The results were to be compared to the values of the VO_2-max capacity of their age group (Andersson 2010, p.37). See appendix 2 for VO_2-max table.

Biering-Sørensens test

The Biering-Sørensen (BS) test involved holding the body prone, over the edge of a bed, with the hips and legs strapped to the bed (in this case test leader was sitting on the participants legs) and the arms crossed over the chest. The test was terminated when the subject could no longer maintain their trunk within 10° of the horizontal or the subject terminated the test. In difference to the original test there was no retest or cut-off after 240 s as in the original study. Though the mean values for estimating risk for lower back trouble were used, this reached from 163 seconds, which indicated back trouble, to 198 seconds or more which would indicate a healthy back (Biering-Sørensen 1984).

2.5 Reliability and validity

The cognitive test batteries reliability was tested through a test-retest, were two participants performed the test battery twice with 24 hours in between. The average method variation was 12,6%, although the distribution amongst the parameters within some tests varied greatly. In fact the highest and lowest numbers was found within the same test – matrix rotation, where accuracy resulted in 0,0 % difference and time per trial resulted in 26,7 % difference.

The validation for these tests within this context has never been examined; however this study aimed explore the possibility of whether these tests could be used to measure performance.

2.6 Statistics

Results were compiled using the statistical analysis program *Statistica*, version 12 (StatSoft Inc., Tulsa, Ok, USA). Statistica was used to compile the data from the cognitive test battery were T-test and M.L. Pearson chi square were used. The two t-test were used to compare group E to group R, and group R to group N where significance level was changed from 0.05 to 0.025 via bonferroni correction.

3. Results

3.1 Cogntive tests

The following two tables are the results from the t-tests were group E and R was compared and also group R and N. P=0.025 in both tables.

Table 1: Metrics from the test battery. E (elite) compared to R (Recreational), * = significance.

Test	Elite	SD	Recreational	SD	*P-value*
Change Detection, (Trials)	8,300	3,592	5,500	3,375	0,089199
Change Detection, Accuracy, (%)	89,60%	17,90%	72,93%	22,48%	0,083141
Dexterity, (Trials)	38,521	7,679	34,100	6,903	0,192487
Dexterity, Completed, (%)	94,02%	5,48%	94,14%	4,82%	0,959906
Go/No-go, Accuracy R, (%)	59,65%	16,13%	48,29%	12,88%	0,098869
Go/No-go, Mean Reaction time, (ms)	424,300	37,639	404,760	29,046	0,210112
Iowa Gambling Task, Money, ($)	2397,500	835,867	2242,500	604,273	0,640343
Keyboard Stamina, Mean, (apm)	390,100	45,081	366,767	30,546	0,192181
Matrix Rotation, Accuracy, (%)	81,50%	11,32%	74,00%	19,55%	0,307646
Matrix Rotation, Mean total time, (ms)	7382,160	2948,302	7922,090	2898,551	0,684509
Pursuit Rotor, Mean time on target, (%)	60,60%	6,83%	61,56%	11,90%	0,837713
Pursuit Rotor, Mean deviation, (pixels)	14,527	1,224	15,951	4,972	0,390827
Situation Awareness, Position accuracy, (units), SINGLE	0,368	0,084	0,417	0,090	0,216548
Situation Awareness, Position accuracy, (units), RANDOM	0,484	0,086	0,486	0,108	0,955786
Situation Awareness, Which animal accuracy, (%), SINGLE	0,450	0,172	0,420	0,140	0,673320
SA W Accuracy, (%), DOUBLE	38,70%	22,39%	38,00%	19,32%	0,941162
Situation Awareness, Angle accuracy, (°), SINGLE	46,060	30,156	44,400	20,304	0,886793
Situation Awareness, Angle accuracy, (°), RANDOM	63,640	39,438	53,900	29,118	0,537703
Tower of London, Mean, (steps)	7,479	1,103	6,534	0,883	0,048605
Tower of London, Mean trial time, (s)	12,176	3,258	11,855	3,721	0,839902
Tower of London, Mean step time, (s)	1,507	0,379	1,614	0,215	0,448145
Time Wall, Inaccuracy, (%)	**7,45%***	**1,08%***	**4,67%***	**1,68%***	**0,000339***
Visual Search, Mean trial time, (ms)	2904,472	1096,576	3219,107	1180,216	0,544576
Visual Search, Accuracy, (%)	96,53%	4,89%	98,37%	1,73%	0,278336

Table 2: Metrics from the test battery. R (Recreational) compared to (Non-players) N. * = significant, ° = tendency.

Test	Recreational	SD	Non-players	SD	*P-value*
Change Detection, (Trials)	5,500	3,375	6,600	4,506	0,602182
Change Detection, Accuracy, (%)	72,93%	22,48%	91,42%	12,79%	0,115314
Dexterity, (Trials)	34,100	6,903	35,200	7,259	0,779163
Dexterity, Completed, (%)	94,14%	4,82%	93,89%	3,43%	0,921713
Go/No-go, Accuracy R, (%)	48,29%	12,88%	55,54%	21,22%	0,420794
Go/No-go, Mean Reaction time, (ms)	404,8	29,0	444,5	93,1	0,225547
Iowa Gambling Task, Money, ($)	**2242,5***	**604,3***	**995,0***	**900,1***	**0,006777***
Keyboard Stamina, Mean, (apm)	366,767	30,546	356,399	55,288	0,642522
Matrix Rotation, Accuracy, (%)	74,00%	19,55%	74,00%	6,52%	1,000000
Matrix Rotation, Mean total time, (ms)	7922	2899	8174	2691	0,873643
Pursuit Rotor, Mean time on target, (%)	**61,56%***	**11,90%***	**45,62%***	**8,81%***	**0,020518***
Pursuit Rotor, Mean deviation, (pixels)	**15,951°**	**4,972°**	**19,816°**	**4,0961°**	**0,029878°**
Situation Awareness, Position accuracy, (units), SINGLE	0,417	0,090	0,446	0,043	0,512894
Situation Awareness, Position accuracy, (units), RANDOM	0,486	0,108	0,578	0,078	0,115443
Situation Awareness, Which animal accuracy, (%), SINGLE	0,420	0,140	0,380	0,217	0,669681
SA W Accuracy, (%), DOUBLE	38,00%	19,32%	38,00%	14,83%	1,000000
Situation Awareness, Angle accuracy, (°), SINGLE	44,400	20,304	61,800	31,220	0,211863
Situation Awareness, Angle accuracy, (°), RANDOM	53,900	29,118	68,600	31,021	0,382881
Tower of London, Mean, (steps)	6,534	0,883	6,966	0,699	0,359025
Tower of London, Mean trial time, (s)	11,855	3,721	17,822	7,918	0,063651
Tower of London, Mean step time, (s)	**1,6141***	**0,215***	**2,028***	**0,185***	**0,002891***
Time Wall, Inaccuracy, (%)	4,67%	1,68%	6,10%	2,52%	0,210007
Visual Search, Mean trial time, (ms)	3219	1180	2853	635	0,533019
Visual Search, Accuracy, (%)	98,37%	1,73%	96,53%	3,48%	0,187134

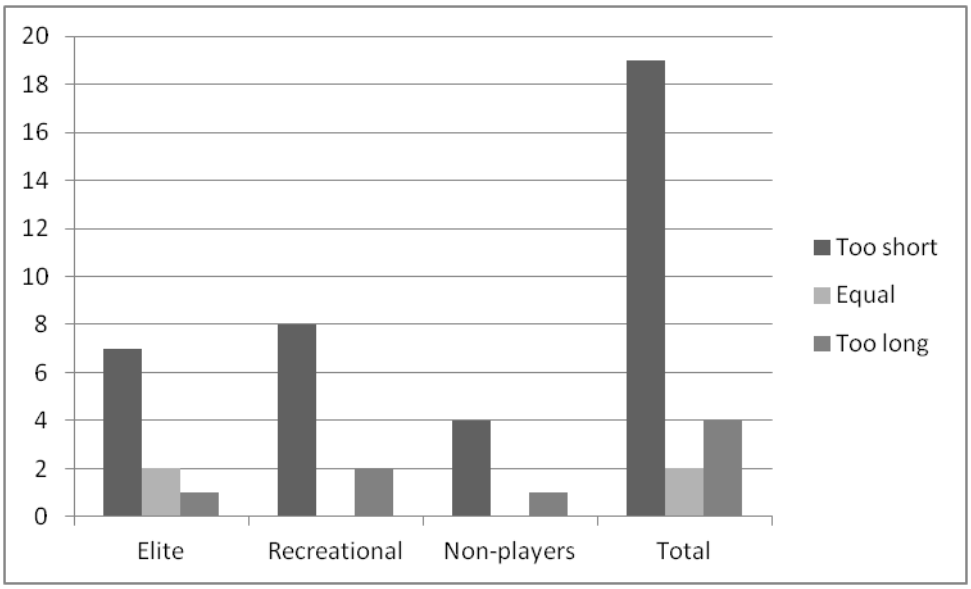

Figure 1: Chi square, nominal data from time-wall test. Y-axis show the number of participants.

Figure 1 shows what number of participants answering too early, too short or equal amount for the majority of the answers in the time wall test. P = 0,48492 after Pearson's chi-square test.

3.2 Fitness tests

Group E estimated VO_2max was 3,83 L/min (SD = 0,38), the average VO_2 consumption for 20-29 year old males is 3,5 ±0,3 L/min (Andersson 2010, p.37), placing the E group in the upper half of the average in their age group, with one individual scoring *low*, eight scoring *average* and one scoring *high* (See appendix 2 for full VO_2max-table).

The elite groups mean result from BS back test was 133 s (SD = 54) which places them within the risk zone for lower back trouble, 163 seconds or lower (Sørensens, 1984). One individual scored over 198 seconds, three individuals between 163 and 198 seconds and six individuals under 163 seconds.

4. Discussion

The BS tests confirm hypothesis 3, *a great number of the elite players will not be able to match the demands for a healthy back according to Biering-Sørensen.* The elite player's results from the BS test indicates unhealthy backs, averages for a healthy back in Biering-Sørensens (1984) study reached from 198 seconds or higher and the lower score, which showed lower back trouble, was 163 seconds or below. The average for E was 133 seconds which is below the score for those with recurring or persistent back trouble.

Although for the fitness test, their aerobic capacity confirms hypothesis 2, *the elite players' aerobic capacity could not be very low according to Andersson, 2010 since that would affect their e-sport performance negatively.* The elite players VO2max was not very low, according to Andersson (2010, p.37) this correlates with previous studies (Haapala 2013, McKee et al 2014, Luque-Casado et al 2013, Lorås et al 2013) which indicates that fitness and cognition goes along to a certain point. There is a performance aspect suggest that the athletes should consider aerobic exercise to prevent their VO_2max to decrease. In addition to that, there is a health aspect that reaches outside of the e-sport context which might be taken into consideration.

The results from the cognitive tests show that hypothesis 1 stating that *the elite players would perform better in a number of these cognitive and fine motor tasks compared to the recreational gamers* was rejected. The elite players did not perform significantly better in any of the cognitive or fine motor task than the recreational players. As displayed in table 1, the only significant difference between E and R is to group E's disadvantage, surprisingly they

showed inferior results in the anticipatory skill test. These results raise the question if team based e-sports puts less demand on the individuals' skill since teamwork becomes a more important factor. These results does not contradict previous research since the recreational players in this study was in fact superior over the non-players in a number of the tests. R showed significantly better accuracy in the pursuit rotor task and also showed a tendency to deviate less from the target than N which confirms the results from Borecki, Tolstych & Pokorski (2013) which was made on recreational players versus non-players. Also coherent with Apelbaums et al. (2013) ideas, R showed superior results in the strategy oriented tasks, both with the net score in IGT and move-time in TOL, as shown in table 1. All of the participants did however outperform the ones in Piper et al.'s (2012) study on the PEBL test battery.

Since the R participants were found through Swedish School of Sports and Health Sciences, it is in order to presume that most of these participants are experienced within sports. The strategic tasks aim to test the open skill capacity and since the tactical tasks were not e-sport specific it is likely that any open skill athlete would perform well in them. The decisive strategic skill for e-sport athletes could to a great extend consist of adapting game play to your opponents through specific knowledge and experience with the special conditions of the game and exploiting them. This is what is commonly known as *metagame*; it seems to be a far more important factor since these tests did not show much differences between professional and recreational players. Of course the athletes need fundamental risk calculation and fast paced planning as well just as Chisholm et al. (2010) reasons.

4.1 Additional findings

Further findings from the anticipatory skill test correspond with the research done by Piper et al. (2012). Shown in the time wall median value, figure 1, responding *too early* (before it hits the mark) is the most commonly occurring result. A plausible reason for this would be that participants are focusing on "catching the object" since it is falling down, a natural reaction is to act right before it passes the mark.

4.2 Future research

Cognitive areas

In many of the games, the team aspects play a large role, especially in the game genres that the elite teams in this study excelled in (FPS, MOBA) and the structure of the games is emphasizing the importance of this area.

Professional teams spend a great amount of time studying their opposing teams strategies and based on that preparing their own strategies, some teams even have analysts to help them out. Preparation probably plays a large role and it is possible that this is a much larger factor to success than any particular individual skill. This might also be a reason why there were no significant differences between E and R, though one could view upon it as a minimum requirement within the skills that R excelled over N - both E and R had enough of these skills, though the elite group manages to distribute their skills better in the game. Therefore preparation and team play is very interesting to study though it is far more difficult to quantify than specific skills.

To measure specific skill, one would have to go deeper than general cognitive tests. Instead, usage of e-sports specific tests and specific tests within each genre would probably generate a more relevant result. A participant could be asked to perform a specific task in match against a computer controlled opponent or perform a special drill designed in the game engine.

E-sports and physical fitness

E-sport training could be combined with preventative training (Manniche et al.1988, Johnsson & Nachemson 2000, Hayden 2012, Hansson 2008) against lower back trouble to prolong their carriers, and post-carriers, without injuries, as mentioned previously it will not have any negative impact on their fine motor skills (Smits-Engelsman et al 2007), but more research needs to be done since functional plasticity associated with specific cognitive training is still relatively unexplored.

This study also raised many thoughts and ideas about weather physical exercise can be of benefit for e-sport athletes, for example what would happen if e-sports athletes with low to average VO_2max enhance their aerobic capacity, and would it have a positive outcome on their e-sport performance? A common argument for excluding physical training is that it would take time from the e-sport specific training and that is something that indubitably

would be needed to be prioritized right. A good way to examine this would be to let a test group trade part of their e-sport specific training for aerobic training, and if they would benefit from the contributed enhancements from aerobic training also within the e-sport area. This would be interesting also on recreational players; however control group would be required.

4.3 Source of errors

One of the major concerns in retrospect was the selection of physiological metrics used for reference. It was at first considered to be advantageous to refer to a population, but it was later realized that by testing group R and N physically would ensure that the testing procedure would have been identical, ensuring greater reliability.

The amount of cancellations from the E participants caused the test group to be small, which was unfortunate since we could discover differences within the group, causing the LOL team to be superior in a number of tasks, but groups would then be too small to actually show any real significance.

A camera crew was filming one of the elite teams could have caused psychological stress and therefore impact the outcome, though instructed to not interfere with the participants.

Minor disturbances such as a participant cell phone rang during the test or “sticky keys” message popped up during testing, which might have caused a distraction for some of the participants.

Some of the E participants were perceived by the test leaders to lack motivation for the tasks, but it was not measured in any way.

4.4 Evaluation of test battery

The adjustments that were made to enhance level of difficulty for the pursuit rotor test was successful, for the manual dexterity test however the disturbance became too great when the noise was altered, making the possibility of hitting the target and scoring high on the test practically left to chance. Decreasing the numbers of trials on a number of tests was a necessity to keep the test sessions within reasonable time, though the situation awareness test would thrive on keeping its original number of trials for reliability.

Reliability has to be taken under greater considerations if used in future research since the reliability test in this study was only performed on two participants which is deficient for the cause. In other words the specific tests within the test battery need to be evaluated individually since there was a large distribution among the individual method errors. Since composing a test battery was one of the aims for the study, the tests with lower method variation would be better for the use of skill testing since they are probable to be having a higher reliability.

When using the IGT, *net score* was the only parameter taken into consideration, it has been shown that low net score correlates with high risk taking (Lage et al. 2011), although other parameters such as gain-loss frequency might tell us more about the athletes actual response to each loss (Newman 2009).

The common denominator between the different tests in this battery is that they are not e-sport specific. These tests might be relevant to establish weaknesses but in order to test strengths there is a need to test them in the kind of more game specific drills as mentioned earlier in the discussion. As seen of test methods within other sports (with exception for strength and endurance sports), strength or endurance tests might only tell a little bit of how well you perform in the actual sport. Therefore use for talent scouting would not be appropriate since it mentions little or nothing about the actual e-sport strengths, though it could potentially be used for pin-pointing weak spots. In case of the later, the time wall test has to be excluded since the elite performed inferior to the recreational group.

4.5 Conclusion

The tested cognitive skills is not noticeable outside the e-sport context and further research needs be done, with e-sport specific tests and also specific within each genre, to make sure elite players will outperform recreational players. This might however indicate that it is not only individuals with predisposed general cognitive skills that will be able to make it to the elite levels, and the skills needed for transition from a recreational to an elite level is hard to measure outside of the e-sport context.

None of the elite e-sport athletes showed low or very low VO_2max which indicates that to perform on an elite level there is a minimum oxygen uptake requirement. On top of that, with all certainty professional e-sports athletes are in the risk zone for, and some even expressed, lower back trouble.

The conclusion to be drawn for any professional e-sports athlete is to continue training e-sport specific training drills and since their occupation requires a lot of time sitting down they have to complement their daily routines with preventative physical training to prevent their aerobic fitness to decrease and above all prevent or, in some cases rehabilitate back injuries.

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Appendix 1 – Source search

Aim: The purpose of the study was to develop and test the reliability of test methods to determine e-sport athletes' strengths, weaknesses and potential use for talent scouting. The purpose was also to investigate their physical fitness.

Hypothesis: 1. The elite players would perform better in a number of these cognitive and fine motor tasks compared to the recreational gamers.
2. The elite players' aerobic capacity could not be very low since that would affect their e-sport performance negatively.
3. A great amount of the elite players will not be able to match the demands for the back test.

What search terms have you used?

E-sports, e sport, video game, computer game, motor, fine motor, cognitive, skills, eye-hand coordination, actions per minute, counter strike, starcraft, moba, multiplayer online battle arena, lol, league of legends, dota, defence of the ancients, VO2max, oxygen consumption, Psychology Experiment Building Language, PEBL

Where have you searched?

Pubmed *EBSCO* *Google Scholar*

Searches giving relevant results

GoogleScholar: e-sport + skill	*613*
GoogleScholar: e-sport + demands	*506*
EBSCO (peer reviewed): e-sport + skill	*2*
EBSCO (peer reviewed): e-sport + demands	*1*
Pubmed: Eye hand coordination + video games	*12*
Google Scholar: pashler + "visual search paradigm"	*427*
Google Scholar: "actions per minute" + sc2	*25*
Google Scholar: UTCPAB + Mental rotation	*73*
Pubmed: deskjob AND back injuries	*1*

Pubmed: office workers AND back injuries	*16*
Pubmed: fitness and cognition	*809*
Pubmed: Fitness and cognition and adults	*540*
Pubmed: Physical fitness and cognitive functions	*418*
Pubmed: Physical fitness and fine motor skills	*16*
Pubmed: Counter strike and motor	*1*
Pubmed: Psychology Experiment Building Language	*5*
Pubmed: PEBL	*12*

Comments

The majority of the used articles were found as references in other studies. *Generally using the word "e-sports" as a search term generated a lot of results concerning just "sports", but not relevant for e-sports.*

Appendix 2: VO_2 L/min –table, G. Anderson 2010

age	very low 1	low 2	avarage 3	high 4	very high 5	elite
15-19	-2,1	2,2 -2,8	2,9-3,2-3,5	3,6-4,2	4,3-	>4,9
20-29	-2,5	2,6-3,1	3,2-3,5-3,8	3,9-4,5	4,6-	>5,7
30-39	-2,2	2,3-2,8	2,9-3,2-3,5	3,6-4,3	4,4-	>5,4
40-49	-1,8	1,9-2,4	2,5-2,8-3,1	3,2-3,8	3,9-	>4,9
50-59	-1,6	1,7-2,1	2,2-2,4-2,7	2,8-3,3	3,4-	>4,5
60-69	-1,3	1,4-1,8	1,9-2,1-2,3	2,4-2,8	2,9-	>4,0