TITLE: Insomnia and problematic gaming: A study in 9 low- and middle-income countries

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ABSTRACT:

Study Objectives: To investigate (i) the prevalence and incidence of online and video gaming disorder in an African population, and (ii) whether gaming is associated with sleep disorders and psychopathological symptoms, including anxiety and depression.

Methods: Data were collected in South Africa, Cameroon, Morocco, Rwanda, Tunisia, Gabon, Nigeria, Ivory Coast and Senegal. Participants were students aged of 24 ± 2.8 years. Problematic gaming, sociodemographic items, insomnia, associated comorbities, depression and anxiety were measured. The effect of continuous gaming time (after 1, 6 and 12 months) on severity of sleep disorders and the distribution of gamers per country and per type of device were also calculated.

Results: African gamers expressed a preference for online gaming more than video gaming. Men played video games for an average of 14 hours per week, and women for around three hours per week. The smartphone was the favourite gaming tool for both men and women. Effect of continuous gaming time on the decrease of sleep is significant ($F(2.1) = 40.26$; $p < 0.001$). After 1 month, participants has no clinical insomnia, but after 6 months they developed subthreshold insomnia and clinical moderate insomnia. Problematic gaming was not associated with anxiety and depression but was associated with an increased of musculoskeletal impairments.

Conclusions: After 6 months of continuous gaming time, sleep is affected. Problematic gaming, regardless if it is video or online; induced a clinical insomnia. The more months a participant spent gaming, the higher the chance for experiencing sleep disorder symptoms.

Keywords: sleep, insomnia, gaming addiction, problematic gaming, online gaming, video gaming, africa, prevalence, anxiety, depression

INTRODUCTION

In recent years, a number of factors have increased in contributing to the risk of developing psychological stress and mood disorders, with these being risk factors in the environment and people's lifestyles [1-5]. This complex combination of environmental and psychological stress may contribute to developing neurological dysfunctions, such as sleep disorders. Although some sleep disorders are consequences of cortical imbalances [6], including insomnia and restless leg syndrome, lifestyle can influence their incidence considerably [7-10]. New technologies are part of this lifestyle, including the internet and gaming, which may affect mental health and may lead to the development of addictive behavior particularly in young individuals [11-14]. The use of smartphones, computers, and video games or online gaming can disturb the circadian process [15-19]. Moreover, many studies revealed the correlation between cognitive impairments and sleep disorders [20-23]. Sleep disorders often increase when individuals have mood and anxiety disorders, deficits in attention or perception, or when individuals live under stressful conditions (i.e., low income, working night shifts, living with neuropsychiatric disorders without family support) [2, 21-24]. Authors also report there is a link between behavioural and medical risk factors (i.e., high-blood pressure, obesity, and smoking) and sleep disorders [25-27], as well as between lower quality of life and a stressful environment and the occurrence of sleep disorders [7]. Recently, a negative correlation was found between psychopathological symptoms (i.e., anxiety, depression and stress) and the development of behavioral problems, such as decreases in psychological wellbeing [5, 10, 28]. It has also been reported that the presence of or exposure to light can disturb the circadian rhythm, the melatonin cycle and cerebral plasticity [6]. To fall asleep, inhibition increases, while excitation decreases. During this process, different sleep stages occur, and neurons build new networks while replacing and repairing tissues and consolidating memory. Accordingly, light-emitting technology may affect the quality and duration of sleep [29]. Wireless devices including smartphones, laptops or tablets may therefore affect sleeping patterns as they rely on backlighting. Recent reports suggest a higher incidence and prevalence of behavioral disturbances in children and adolescents exposed to technologies and playing online games for several hours per week at home [11, 30, 31]. In addition to behavioral disorders related to the utilization of new technologies, the phenomenon of addiction may be another consequence, which are

now being included under an addictive behaviors category in the 11th update of the World Health Organization's International Classification of Diseases (ICD-11), Gaming Disorder generally refers to a diagnosis characterized by uncontrollable and persistent playing of video and digital games that is harmful to an individual's wellbeing, often leading to addictive behaviors. Rather than engaging in the offline world, an addicted user devotes the majority of his or her time to gaming. The addicted gamer often isolates him/herself from others, ignores more important responsibilities, and is often preoccupied with obtaining higher status / rankings / achievements in his/her favorite computer game. This may be the case for using gambling and gaming on computers and consoles as the available evidence indicates gaming with wireless devices, such as smartphones, does not appear to be problematic [32]. Similar evidence was reported for the use of online social networking sites and Massively Multiplayer Online games (MMOs) [12, 33]. Although research in the area of Gaming Disorder is progressing [34], few studies have explored the association between gaming behavior and sleep disorders [35-44]. Considering the impact of light, a stressful environment and visual stimulation on sleep mechanisms and the risk excessive use of gaming may pose for sleep and psychopathology, it may be hypothesised that gaming decreases sleep quality and increases sleep disorders and psychopathological symptoms. This hypothesis has not been reported in the available scientific literature yet. Some associations or indirect links were found between the use of technologies (internet, video games, and electronic media) and factors associated with sleep (sleep quality, sleep duration, and sleep habits) for preadolescents, adolescents and older adults m[35-44], but a clear correlation between gaming and sleep disorders has not yet been established. Specifically, there exists a gap in knowledge regarding the assessment of gaming behaviors and their impact on sleep in developing countries, low- and middle-income countries. There is a lack of data particularly for Africans countries, which face the same problems related to the use of the internet and gaming [45-49]. With the popularity of consoles, such as Playstation and the Xbox, and the possibility to use various applications on smartphones and tablets due to easy access to Wi-Fi and mobile data, gaming has become a part of life in Africa, similar to Europe and North America. Recently, some reports estimated that African countries such as Nigeria have over 146,866,356 active mobile phone lines, with mobile users interested in available entertainment content (BBC 2016) on internet, which may impact negatively on users' health (including sleep) in some cases [45, 46]. It was also suggested recently by Wittek et al.[50] when assessing prevalence rates and

predictors of video game addiction in a multicultural sample including native Norwegians and immigrants that the geographical region where an individual is born may play an important role in addictive behavior, and they reported there were more addicted gamers who originated from African, Asian and central American countries compared with gamers born in Europe and North America. Prevalence of gaming disorders was reported in Europe, Asia and North America [14, 31, 50-54]; while no data exist for prevalence in African countries as well as their association with sleep disorders. Given the lack of knowledge in the field of gaming and sleep disorders in African countries, the purpose of this study is to investigate (i) the prevalence and incidence of online and video gaming in African populations, and (ii) whether gaming is associated with sleep disorders and psychopathological symptoms, including anxiety and depression. The current study furthermore aims to provide information on gamer profiles in Africa, including gender, sociodemographic characteristics, and the association between sleep disorders and different types of devices used for gaming.

MATERIALS AND METHODS

1-Ethics committee

This research program was approved by the ethics committee of research on humans of the Université de Montreal, Canada, and by the administrator or dean of the universities at which recruitment took place. All subjects were volunteers and signed a consent form and were recruited through the respective admissions offices. All participants were contacted via the email lists of the admission office, and data were collected within the period of one year and computed in an external database. This database was secured outside the public network and was shared only with the investigators involved in the project.

2-Sample Characteristics

Participants were students aged between 18 and 40 years old (24 ± 2.8 years). The response rate to the online survey was 75%. Characteristics of the sample are detailed in Table 1. The initial population was $N = 120.460$ participants. After analysis of answers to the questionnaires used to categorize gaming and sleep disorders, and

after removing incomplete forms, the final sample included 10.566 participants. Approximately 11.4% of the participants identified themselves as gamers.

3-Data collection

The participants were contacted by email. The online questionnaire which was filled in by the participants included a consent form on the second page, following a description of the study in French and English. Consent was required to participate in this project. The average time to answer all questions was 20 minutes. The questionnaire was configured to be filled in only once by the same email address, and duplicates and incomplete forms were removed. Responses were collected between November 2015 and June 2017.

4-Psychometric properties of questionnaires

This research was performed with a combination of quantitative and self-report questionnaires assessing insomnia and quality of sleep, anxiety and depression, problematic gaming, medical history, sociodemographic and socioeconomic data of participants. The data collected also included global wellbeing, smoking, physical activities and suicidal tendency of participant. For every questionnaire, an additional question was added to estimate decrease of health status across time. The participant was requested to report if they experienced the respective problems (i.e., "Do you have problems to maintain sleep, falling asleep", etc.…) 1 month, 6 months and 12 month before the study. The questionnaires used in this investigation were the following:

Insomnia Severity Index (ISI): This questionnaire is widely used to assess insomnia and associated parameters, including lack of sleep and sleep quality. It was developed by Morin and al. in 2001 [55, 56]. The internal consistency of the ISI was excellent (Cronbach's $\alpha = 0.92$), and each individual item showed adequate discriminative capacity ($r = 0.65$-0.84). The area under the receiver operator characteristic curve was 0.87 and suggested that a cut-off score of 14 was optimal (82.4% sensitivity, 82.1% specificity, and 82.2% agreement) for detecting clinical insomnia. An ISI score between 0 and 7 is an insomnia considered clinically non-significant, between 8 and 14 as a subthreshold insomnia, between 15 and 21 as a moderate clinical insomnia, and between 22 and 28 like a severe clinical insomnia [55, 56].

A problematic gamer's behavior survey based on Griffiths' calculator's model [57, 58]: A short questionnaire developed by researchers involved in this project was used and included the following questions: How many hours do you play per day? How many days you play in the same week? What type of games do you usually play? Do you play for excitement? Do you become restless and excitable if you can't play? Do you try to cut down your playing but you can't? Do you forget social activities, education, family or homework for gaming? How much money you spent in your gaming? Following Griffiths et al. 2004, if the participant answered ''yes'' to more than four questions, they were categorized as a problematic gamer.

Mental Health Profile of Etindele (MHPE): This questionnaire was developed and validated by Etindele et al. in 2016. It estimates and categorizes the following sections in a time-efficient way: depression, anxiety, physical activity, cognitive impairment, suicidal behaviour, well-being, sleep (quality and duration), medical history (familial and individual) and sociodemographic data (age, sex, education). In total, the questionnaire included 72 questions ranging from 0 to 4 where possible answers ranged from ''yes or no'' and ''none, often, very often'', except for sociodemographic data. Every section above included eight questions and had a maximum score of 32. The scoring used was as follows: under 16 (no or low risk), between 17 and 23 (medium risk) and over 25 (high risk). Additional psychometric properties are detailed in previous studies [2, 3].

The Hospital Anxiety and Depression Scale (HADS): This is a self-administered scale including 14 items, divided into two subscales of seven items (Anxiety or HADS-A, Depression or HADS-D). It contains no somatic items that can be confused with the symptomatic manifestations of a disease. Each item is scored on a scale of 0 to 3. A score is generated for each of the two sub-scales and for the entire HADS (HADS-T). The scoring is similar for anxiety and depression and following scores there are three categories of symptomatic levels: non-cases or asymptomatic ones (scores ≤ 7); probable or borderline cases (scores 8-10); clearly or clinically symptomatic cases (scores ≥ 11). The duration of administration is approximately five minutes and psychometric properties are detailed in previous studies [59, 60].

Country	Number of Gamers	Male	Female	Online Gamers	Video Gamers	Mean Age	Mean Hours of Gaming/week	Mean Months of Gaming/ gamer	Type of sleep disorders reported	P-value
South Africa	2200	1633	567	1934	266	21±3	17±2.5	14±2	Insomnia	0.00063
Cameroon	1306	1292	14	706	600	19±3	10±1.75	19±1	Insomnia	0.00024
Ivory Coast	850	812	38	700	150	23±2	12±1.25	13±1	Sleepiness/ Insomnia	0.00008
Gabon	500	497	3	420	80	20±2	6±0.5	15±1	Sleepiness	0.0031
Morocco	1100	1035	65	750	350	20±2	18±2.5	18±2	Insomnia	0.0006
Nigeria	1310	1010	300	910	400	25±2	12±2.25	13±1.75	Sleep apnea	0.0078
Rwanda	710	620	90	690	20	25±1	8±2	10±2	Sleep apnea	0.0352
Sénégal	1090	997	93	805	285	22±2	6±2.5	11±0.25	Sleepiness	0.0276
Tunisia	1500	1470	30	1085	415	26±4	20±2.5	26±2	Insomnia	0.00058

Table 1: Characteristics of the final sample of gamers per country, with type of gaming, mean hours of gaming and type of sleep disorders

5-Statistical Analysis

The normal distribution of the data was analyzed using Kolmogorov-Smirnov's test. To analyse differences between online and video gaming, responses were converted to a dichotomous variable. All participants with an incomplete survey were not included in the analysis. From the initial number, 2114 respondents were excluded. The final sample employed for analysis was 10.566 participants. Online gaming included games played via online social networks, the internet, smartphones and tablets. Playing classical consoles like Playstation and Xbox was considered as video game. Spearman's rank was used to analyse the relationship between the demographic and socioeconomic data, type of sleep disorders, gender, age, level of education, type of gaming (video or online) and time spent gaming. Mann-Whitney's non-parametric test for independent samples was employed to compare time spent on gaming as a continuous variable between two groups (male and female). The same test was used to compare video gaming for males and females. The Kruskal Wallis test was used to assess differences in hours of gaming between males and females. The evolution of sleep disorders as a function of playing time was estimated with a repeated measures analysis of variance while considering an intra-person factor since the measurements were made for the same individual (periods of time were one month, six months and 12 months). Statistical tests used an alpha of 0.05 as level of significance. Data analysis was performed using PRISM (Graph Pad Prism, version 7.0.0.159, Graph pad software).

RESULTS

The study was conducted in four low- (Cameroon, Gabon, Rwanda, and Senegal) and 5 middle-income countries (South Africa, Nigeria, Morocco, Tunisia, and Ivory Coast). The nine countries chosen in this study were included because they have been ranked in the top 20 more highly developed African countries in terms of technologies use, internet connectivity and potential for the market of gaming and gambling (measured via the increased number of gamers, presence of casinos, expenses for gaming purposes, etc.) in the last four years, according to the most recent annual report of the International Telecommunication Union (ITU 2017), who regularly publish the `"measuring the information society report", which is the world's reference in terms of data related to the development of communications, technologies and connectivity [61]. From an initial sample of

12680 people, 10566 were fully gamers according to the inclusion criteria which are a minimum of 6 hours of gaming/week and use of online or video game. Inside this population, 88.64% (9366 participants) are men and 11.36% (1200 participants) are women. The mean age of the sample was 22.33±2 years old. These results are very interesting because they revealed a disparity in interest of men and women for gaming. In terms of hours of week and according the results of the problematic gamer's survey, men play online and video games 7.8 times more than women; and this trend was the same for all the countries contributing to this study (Table 1). Inside the sample, the proportion of people playing classical video games or online games was different. It was observed that 75.71% of the participants (8000 participants) were online gamers and only 24.29% (2566 participants) played video games. African gamers expressed a preference for online gaming more than video gaming. This behaviour was the same for both women and men. Analysis shows that 89.42% (1073 people) of women liked online gaming compared to video gaming used by only 10.58% (127 people) of women. For men, the trend was less important because majority of them played online games (55.52%, 5200 men).

In line with previous results, the average number of hours of gaming was computed and analysed for both genders. Men have an average of almost 18 hours per week of online gaming, compared with women who have close to 6 hours of online gaming per week. Concerning video gaming, the average number of hours was less than that for online gaming. Men played video games more than women. Men played video games for an average of 14 hours per week, and women for around three hours per week. Regardless of gender and type of gaming, the main emerging observation is that men played for longer periods of time than women when aged between 19 and 26 years. The analysis revealed that time spent gaming correlated with the experience of sleep disorder symptoms. According to the characteristics of the population and following the performance of a logistic regression analysis, Figure 1 demonstrates an association between gaming and the presence of sleep disorders (self-reported by participants). The more months a participant spent gaming, the higher the chance for experiencing sleep disorder symptoms. In line with previous results presented above, this phenomenon holds true for both, online gaming and for video gaming. The correlation between online gaming and sleep disorders symptoms was stronger than that with video gaming. In this cross-sectional study, analysis of the answers to ISI showed a temporal decrease of sleep with online gaming, beginning at 10 consecutive months of gaming. For the same length of video gaming, a stagnation in self-reported sleep disorders was observed with video gaming.

By comparing the sub-sample of gamers using the internet for gaming (i.e., on tablets, smartphones, and computers) with the other sub-sample of gamers using consoles for gaming during the same period of time, the prevalence of sleep disorders was found to be higher for the sub-sample playing online. the more developed a country is in terms of connectivity and technologies (i.e., South Africa, Nigeria, Cameroon and Tunisia).

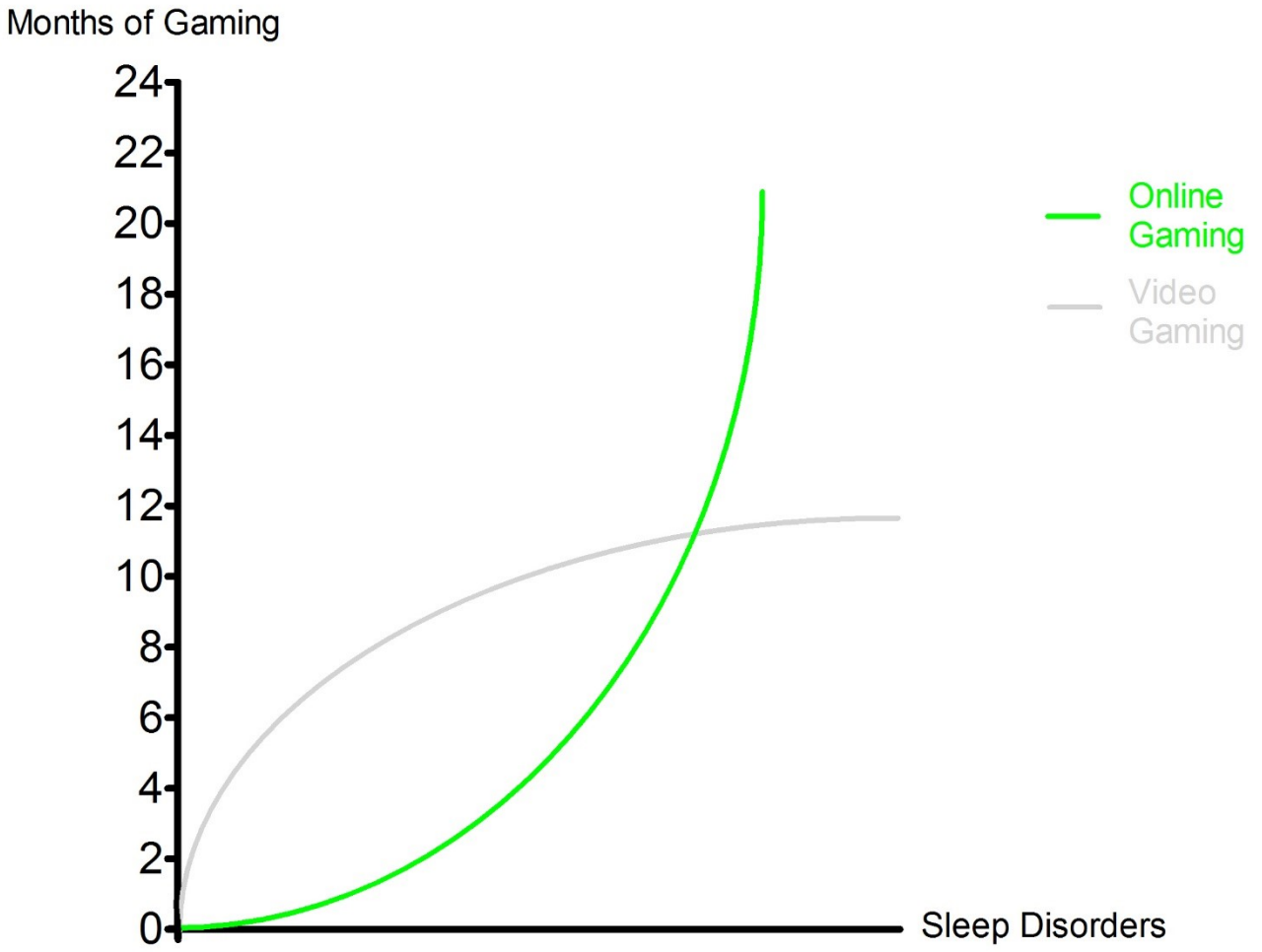

Figure 1: Correlation between gaming and evolution of sleep disorders

Figure 2 showed the progressive deterioration of sleep with increase of the continuous gaming time (1, 6 and 12 months). Repeated measures analysis of variance showed that, effect of number of months of gaming on the decrease of sleep duration and sleep quality -in another word an increase of the ISI score of the participant- is significant ($F(2.1) = 40.26$; $p < 0.001$). After 1 month, participants mean score of the

ISI is 6 (no clinically significant), but after 6 months ISI score increases at 14 (subthreshold insomnia) until 21 (clinical moderate insomnia).

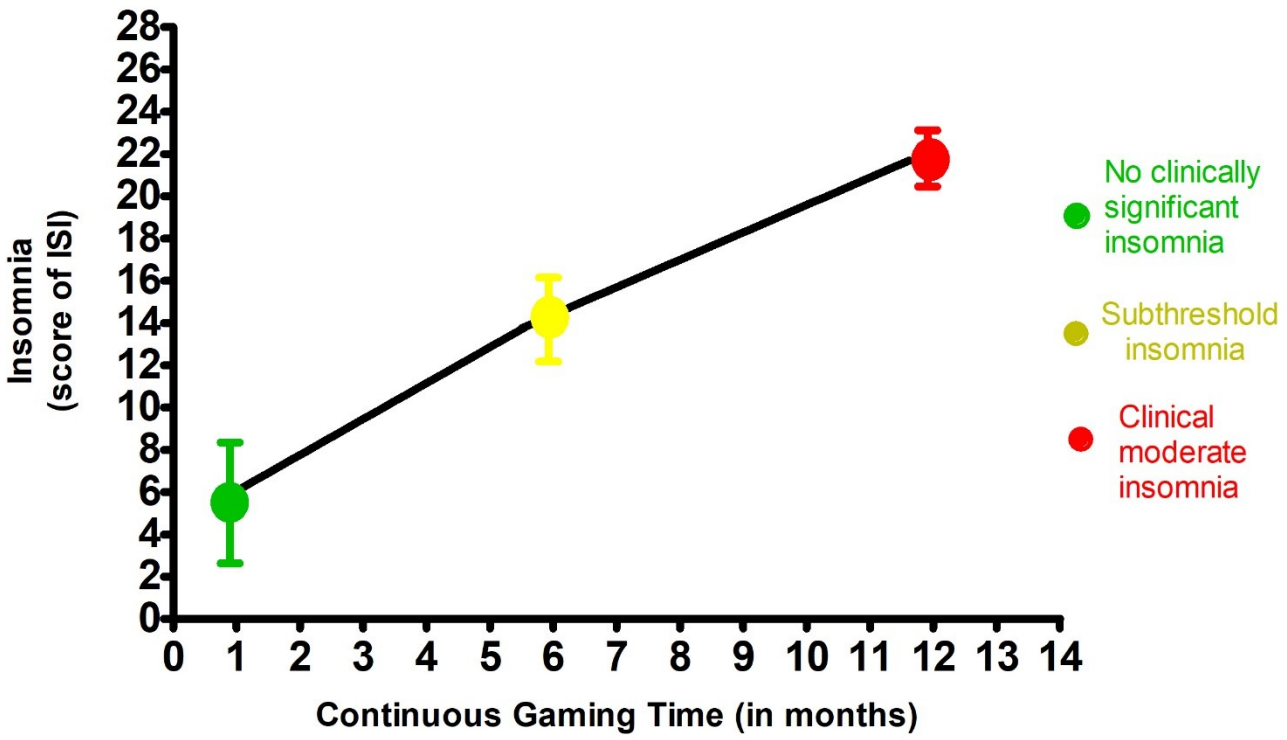

Figure 2: Decrease of sleep with increase of the continuous gaming time (1, 6 and 12 months). The errors bars indicated the confident interval at 95%.

Table 2 shows that the favourite gaming tool was the smartphone, followed by the computer in the second and the console in the third position. Tablets were the device least used for gaming. The trend was similar for all countries except for Gabon, where participants used their tablets more than smartphones and consoles. The highest number of smartphone gamers was found in South Africa, followed by Cameroon and Tunisia. Senegal and Nigeria were the countries with more computer gamers. Cameroon had the largest proportion of gamers using consoles (Playstation and Xbox), followed by Tunisia, Rwanda and Nigeria. Participants from the Ivory Coast did not use tablets for gaming. The Ivory Coast was followed by Senegal and Cameroon as countries with few tablet gamers.

Country	Number of gamers	Gamers using smartphones	Gamers using tablets	Gamers using computers	Gamers using consoles
South Africa	2200	1500	14	600	86
Cameroon	1306	700	13	186	407
Ivory Coast	850	230	0	520	100
Gabon	500	153	217	113	17
Morocco	1100	450	41	489	120
Nigeria	1310	456	83	617	154
Rwanda	710	271	18	229	192
Sénégal	1090	387	7	653	43
Tunisia	1500	800	26	480	194

Table 2: Proportion of smartphone gamers, tablets gamers, computer gamers and consoles gamers per country

The final sample of 10.566 subjects was used in the study. In this population, 66.82% of the participants were aged between 18 and 24 years, a significant proportion. Women represented 11.36% of the participants. Most of the respondents were undergraduates (99%). Table 3 presents the self-

reported participant's experience of psychopathological symptoms reported by participants for one month, six months and one year of gaming. Family history computation revealed that 92.85% of the participants had a healthy medical history. In the sample, no breathing disorders or cardiovascular diseases were present. All clinical parameters (i.e., sleep components, self-reported diseases, and medication) were associated with experiencing anxiety symptoms ($p < 0.0001$, Kruskal Wallis test) and depression symptoms ($p < 0.0001$, U Mann-Whitney's test). The analysis of the data from the Hospital Anxiety and Depression Scale showed that 2% (n=212) of respondents experienced anxiety symptoms, ranging from normal (no symptoms of anxiety, 1.42%, n=150) to moderate (0.43%, n=46); and depressive symptoms ranged from 0.47% of participants reporting no (0.35%, n=37) to moderate (0.09%, n=10) depressive behavior and symptoms. Both have a good correlation with the increase of medication (13%) reported by participants after one year of gaming ($p < 0.0001$, Spearman's rank). The increase of medication was estimated by asking participants to report how many drugs/antibiotics/anxiolytics/anti-inflammatories they took after one month, six months and one year; and by computing their answers to the question ''How many times did you make use of the respective treatment (s) per day during the same three periods''.

Socio-demographical data	**Number (%)**	**After 1 month of gaming**	**After 6 months of gaming**	**After 1 year of gaming**	**p-value**
Age					
18 - 24	7060 (66.82%)				
24 - 30	3400 (32.18%)				
30 - 36	106 (1%)				
Gender					
Male	9366 (88.64%)				
Female	1200 (11.36%)				

Education					
Undergraduate (First year)	6100 (57.73%)				
Undergraduate (Second year)	3406 (32.23%)				
Undergraduate (Third year)	1060 (10.03%)				
Other (certificate, Master, PhD)	23 (0.21%)				
Family history of neurological. musculoskeletal. respiratory or cardiovascular disease					
Cardiovascular disease (*hypertension, myocardial infarction, heart failure*)	0 (0%)				
Musculoskeletal disease (*carpal tunnel syndrome, tendinitis, back pain, tension neck syndrome*)	280 (2.65%)				
Neurological disease (*epilepsy, dementia, brain tumor, cranial trauma, headache, Alzheimer's*)	129 (1.22%)				
Breathing disease (*sleep apnea, bronchitis, asthma, lung cancer*)	0 (0%)				
Other (*any disease not included in the categories above like stomach ulcer or allergy*)	346 (3.27%)				
None	9811 (92.85%)				
Number of respondents with neurological, musculoskeletal,		**After 1 month of gaming**	**After 6 months of gaming**	**After 1 year of gaming**	**p-value**

respiratory or cardiovascular disease					
Cardiovascular disease	0 (0%)	0 (0%)	10 (0%)	70 (0.66%)	0.00032
Musculoskeletal disease	180 (1.7%)	220 (2.08%)	360 (3.4%)	880 (8.33%)	0.00087
Neurological disease	129 (1.22%)	209 (1.98%)	229 (2.16%)	408 (3.86%)	0.0041
Breathing disease	0 (0%)	10 (0.09%)	16 (0.15%)	45 (0.42%)	0.0078
Other	217 (2.05%)	273 (2.58%)	330 (3.12%)	456 (4.31%)	0.00067
None	10040 (95.02%)	9854 (93.26%)	9621 (91.05%)	8707 (82.4%)	0.00056
Number of respondents with depression symptoms (according answers to HADS-D)		**After 1 month of gaming**	**After 6 months of gaming**	**After 1 year of gaming**	**p-value**
None	37 (0.35%)	58 (0.55%)	78 (0.74%)	78 (0.74%)	0.0026
Moderate	10 (0.09%)	10 (0.09%)	11 (0.1%)	14 (0.13%)	0.0034
Mild	4 (0.03%)	8 (0.07%)	8 (0.07%)	11 (0.1%)	0.0031
Severe	0 (0%)	2 (0.01%)	4 (0.03%)	7 (0.06%)	0.0004
Number of respondents with anxiety symptoms (according answers to HADS-A)		**After 1 month of gaming**	**After 6 months of gaming**	**After 1 year of gaming**	**p-value**
None	150 (1.42%)	261 (2.47%)	323 (3.05%)	473 (4.47%)	0.0063
Moderate	46 (0.43%)	56 (0.53%)	80 (0.75%)	107 (1.01%)	0.00047
Mild	10 (0.09%)	14 (0.13%)	17 (0.16%)	34 (0.32%)	0.00085
Severe	6 (0.05%)	6 (0.05%)	10 (0.09%)	26 (0.24%)	0.0002

Table 3: Self-reported experience of psychopathological symptoms after playing for 1 month, 6 months and 1 year

DISCUSSION

The aim of this research was to investigate the association between gaming and sleep disturbances in African populations. The prevalence and incidence of sleep disorders for problematic gamers has not been well documented before, and the present cross-sectional research filled this gap in knowledge. The main findings were the following: time spent gaming correlated with the experience of sleep disorder symptoms for both men and women, despite the difference of time spent gaming across sexes (men play online and video games 7.8 times more than women). The most frequently reported sleep disorders in this study were insomnia (*n*=6106, 57.8% of the sample), sleepiness (*n*=2440, 23.09% of the sample) and sleep apnea (*n*=2020, 19.11% of the sample). In the same population, a small proportion of respondents reported experiencing insomnia and sleepiness simultaneously (*n*=850, 8.04% of the sample). Based on a retrospective account of participants, problematic gamers experienced the first symptoms of sleep disorders after ten months of intensive gaming, with an average of 16 hours of gaming per week. This cross-sectional study found a preference for online gaming with 75.71% of respondents (*n*=8000) who preferred smartphones for gaming and 36.78% of respondents (*n*=3887) who used their computers for gaming. A slow decrease in global health of participants was also reported after one year of gaming based on participants' retrospective self-reports regarding sleep disorders and musculoskeletal diseases (*n*=880, 8.33% of gamers) and neurological diseases (*n*=408, 3.86% of gamers). These results are in line with previous studies which reported more negative effects of gaming on health outcomes for problematic gamers, compared with non-gamers [21, 62].

Relation between socioeconomic status, sleep and gaming

There are several sleep disorders reported by the literature during the last forty years. Each sleep disturbance has his own processing and affects specific layer of population. For example, insomnia is more prevalent in elderly populations than in adolescents [63]. There is also sleepwalking and experiencing nightmares, which are more prevalent with children than with adults [63]. The experience of sleep problems may be impacted upon the individuals' environment, including the respective country individuals reside in, and their social class [62, 64, 65]. Socioeconomic status and technology use are additional external factors, which may impact sleep quality, and which have been reported as important risk factors for the experience of mental health problems [57, 66, 67]. While

this hypothesis was recently tested for gaming researched in developing countries [57, 64], the present study indicates there are relationships between experiencing sleep disorder symptoms and the extent of gaming in Africa, as has been recently reported [45]. The present study also revealed disparities in the use of gaming devices across different countries in Africa. The most recent annual report of the International Telecommunication Union (ITU 2017) reported all the 9 countries were this research was performed ranked among the 20 most developed countries in technologies and connectivity in Africa. Our findings associates this level of technologies use with a significant rate of problematic gamers. The more developed a country is in terms of connectivity and technologies (i.e., South Africa, Nigeria, Cameroon and Tunisia), the more problematic gamers are found. Problematic gamers in this sample showed a preference for devices allowing internet-based games (smartphones, computers and tablets). Following the same trend, there were less problematic gamers in low-income countries (i.e., Gabon and Rwanda), and all problematic gamers in these countries reported their preference for gaming online. This may be due to the price of consoles, which are still expensive for people living with low salaries common in Africa, where in 2017 the average gross domestic product (i.e., the purchasing power parity per person per year) of the populations remains among the weakest in the world, as indicated by the annual report of the International Monetary Fund (IMF) in 2017. The average price of a console-based video game, such as the Playstation 4, is USD300, which equates to nearly a tenth of the annual income of a Cameroonian or a seventh of the annual income of a Rwandan. The opposite phenomenon was observed during the past ten years where it became easier to purchase a smartphone with a telecommunication provider or through an online market place, such as eBay or Amazon, and then downloading free games using application portals, such as the Playstore and Appstore. This may explain why wireless devices including smartphones and tablets are more popular than classical consoles for gaming in these countries.

Relation between technology use, gaming, sleep and education

The mobile gaming market has grown considerably in the last ten years. It is easy to download a mobile game on a wireless device and the majority of these games are free, compared with the expensive price of a single console game which tends to be priced at an average of USD 30. The present research found that gaming and smartphone use were associated with sleep disturbances [39, 40] Individually, gaming and using wireless devices are associated with addictive behaviours (i.e. gambling) [11]. Addiction is often associated with mood disorders

which are strongly associated with sleep disorders [62, 68]. The results of the present study suggest that there appears to be a similar relationship between gaming (specifically online gaming) and the experience of sleep disorders and psychopathological symptoms.

Education plays an important role in the relationship between gaming and sleep disorders because the majority of studies investigating gaming and its consequences on mental health were performed with samples of college and university students [69]. In several studies, the populations affected by gaming addiction are adolescents and young adults [13, 31, 70]. There is a high prevalence of sleep disorders in students in college and university populations [2, 24]. The present study questions the importance of education, in the interplay between problematic gaming and sleep disorders. More investigations are necessary to elucidate if this association exist or not.

Relation between gaming and the prevalence and incidence of diseases

The present research indicates that the more time a person spends gaming, the more general health problems they experience. Respondents to the present research reported that after one year of gaming, they noticed an increase of musculoskeletal diseases, such as back pain (8.33%). Video and online gaming require minimal physical activity. This may explain why there was an association between the experience of musculoskeletal diseases and gaming. After one year of gaming, participants reported more neurological diseases, such as sleep disorders (3.86%). Some researches associated video gaming (specifically action video games) with benefits for attention and spatial memory [15, 71], while many articles reported distraction and mood disorders associated with gaming [14, 44, 72]. There is still no consensus with regards to the causal links between these variables and more research is needed to assess the (positive and negative) effects of gaming on neurological function. In the present study, the nature of the collected data cannot provide an explanation for why there were 408 respondents who had experienced neurological disorder symptoms and to what extent these were considered to impair them. It is also important to notice that psychopathologies such as anxiety and depression are not influenced by the duration or the period of gaming. Less than one percent of the population reported anxiety symptoms before or after becoming a problematic gamer. This may indicate that gaming addiction is not necessarily associated with psychopathological symptom experience as has been indicated in the case of pathological gambling by Dufour et al. in 2014. Finally, many other health problems, such as impaired vision (4.31%), appeared within the period

of one year's worth of gaming. The cause may be environmental or not in relation to gaming, and its distribution in the population was not statistically significant to be included in the analysis.

Even if biological measures do not confirm the exact number of new cases of diseases, 17.8% of the sample (more than 1880 participants) reported the appearance of diseases they did not have before they had started gaming. Taking into account individuals who did not accurately report their health status, including missing data, it is possible that the number of individuals developing diseases because of gaming may be higher than the current results suggest.

Comparison between Africa, Asia and Europe

Our findings are similar with those reported in Asian countries and Europe. Prevalence of gaming disorders in our african sample is closed to findings in adolescent and student populations in Asian countries, associated with addictive behaviors and a high prevalence of problematic internet use [53]. A number of studies suggested that online gamers with longer weekly gaming hours tend to have more severe depressive and Internet addiction symptoms [73], as well as sleep disorders [74, 75]. In Europe and Asia, problematic gamers also tend to develop somatic and musculoskeletal diseases, due to their poor physical activity and their progressive addiction [53, 73, 75]. The present findings did not show a significant association between mood disorder symptoms and gaming, but the current literature reports associations between online and video gaming with anxiety and depression. Our hypothesis is the following: problems associated with excessive gaming may be more of a physical nature in African countries as showed by the present research, whereas research in many other countries (Uk, Turkey, China, Norway, USA) indicates that excessive gaming is associated with mental health problems like sleep disorders, anxiety, depression, and cognitive decline [14, 21, 42, 43, 73]. The prevalence is similar for adolescent and students, males and females [14, 72, 74]. Despite the increase of studies on problematic gaming and technology-related disorders around the world, this topic remains understudied in low-income countries and in particular in Africa. Wittek and Al in 2016 showed the differences prevalence of gaming disorders regarding the place of birth and was among the first to think about the importance of gaming disorders in Africa [50], while the prediction of the economic and health impact of gaming in Africa was in parallel made by few authors like Barr and Osiakwan [61, 76]. The present study demonstrates prevalence and incidence of gaming disorders in African

countries and provides an objective comparison with prevalence in other regions of the world, mainly North America, Europe and Asia (China, Korea and Taiwan) [14, 31, 50-54].

Limitations of the present study

The research design employed had a small number of limitations. The first limitation is the lack of clinical and medical data of participants. Depending on the country, it was not easy to access well-documented and complete medical records because of the complex administration mandatory to obtain this information. The delays in the research process also played an important role in the decision to not include clinical record in the analysis. The second limitation was the languages used in the questionnaire. Many countries where the research was performed have an additional language which citizens use on a daily basis. The questionnaire was available in French and English, but it may have been possible to increase the response rate if the questionnaire was available in other languages, such as arabic (which are the main used language in Tunisia and Morocco) and Kinyarwanda (which are the main language speak in Rwanda in equal proportion of french, english and Swahili). The third limitation was the number of respondents who replied to the questionnaire, because from the initial sample (*N*=120.460) only 11.4% of participants met the inclusion criteria. This may be due to the fact that several questions focused on gaming, and given the smaller number of gamers, overall participation rates were relatively low. The small percentage of respondents (11.4%) may also be due to a lack of interest for the research and the cultural habits where empirical and biomedical research are not well embedded in culture and inside the African healthcare system [77]. It can also be caused by fatigue effects of individuals being asked to complete surveys and questionnaires more frequently (e.g., questionnaire issuing for marketing, survey made for advertising purpose, questionnaires shared through social media like facebook and whatsapp, survey inside mobile games or AppStore), in addition of the perceived risk of a breach of confidentiality which may decrease people's motivation to participate in research [78].

Conclusion and futures investigations

This study points to the necessity for the global research community to pay more attention to low- and middle-income countries, in regard to the prevalence and incidence of sleep disorders. This sample of African participants experienced a relatively high rate of sleep disturbances, and it is mainly insomnia which emerged as

the main sleep complaints. This study also showed a negative association between gaming (video or online) and the increase of musculoskeletal and neurological diseases as well as various other dysfunctions. Research on Internet addiction and sleep disorders is still in its infancy. There are still data missing on diseases associated with gaming, the sociodemographic and environmental risk factors are not all known, and epidemiological reports on their correlates with metabolic diseases as well as mental disorders are missing specifically for low- and middle- income countries. It is also important to investigate their distribution in the general population, because the majority of studies reported gaming problems for students while children and older people also use the same technologies and may face similar problems. Finally, the current study demonstrated an association between excessive gaming and increased physiological health problems, while the majority of the literature in other countries linked problematic gaming with mental disorders. It appears that the nervous system is more stimulated than the other systems (cardiovascular, breathing, etc.…) by gaming through the visual system and cognitive functions (e.g., memory, perception, attention), but the present research suggests that it is important to investigate the impact of gaming on the rest of the human body in future research. The present research suggests problems associated with excessive gaming may be different based on the respective geographical region; i.e., in this sample of African participants, physiological problems emerged, whereas other research in other countries indicates more mental health problems. This research should be performed in different geographical region where gaming was documented (or not), so it may provide additional information on appearance of physiological troubles in relation with gaming.

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