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B) acquisition of data
C) analysis and interpretation of data
D) manuscript preparation
E) obtaining funding

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Abstract

As esports grow, public authorities have many concerns about the potential negative health effects of this "sedentary" practice. This work proposes a systematic review on the links between esports and physical activity (PA). The research questions guiding this review are as follows: (1) What is the PA level of esports players? (2) Do data exist regarding the influence of participation in esports on players' PA? (3) Based on these findings, what future research questions should be asked and what studies should be conducted? Eighteen studies met the inclusion criteria. The analysis revealed that esports players appeared to be active, exceeding World Health Organization recommendations, in 13 studies and inactive or low-active in four studies. The different populations of players do not appear to have the same degree of PA. High-level, professional, and/or supervised players appear to be more physically active. However, some data are inconsistent, and our review highlights several biases and methodological limitations. Additionally, while we have found no studies providing data on the influence of esports on PA, five studies highlight several factors that could push players to engage in PA. Finally, further research is needed using objective measurement tools and characterizing and accurately distinguishing between players' levels of expertise and the type of game played. The nature and modalities of the PA also need to be clarified. We encourage supplementing these quantitative data with qualitative data obtained through interviews to provide a description and understanding of the influence of esports on PA engagement, re-engagement, retention, and withdrawal.

Keywords: Physical activity, inactivity, electronic sports, video games, influence

Introduction

Context

The competitive practice of video games, also known as esports (i.e., electronic sports), refers to "organised video game competitions" (Jenny et al., 2017). It is therefore distinct from the recreational practice of video games (without ranking or competition). This specific manner of practicing competitive gaming includes different video games (e.g., Call of Duty, Counter Strike, Dota 2, Hearthstone, FIFA, League of Legends, etc.) whose leagues and tournaments have neither the same degree of professionalization nor visibility and which have their own characteristics. The popularity and growth of esports, which is attracting an increasing number of players and spectators, has

been highlighted by numerous academic studies (Anh et al., 2020). Newzoo (2022) estimates that the global esports market would have generated $1.1365 billion in 2021. According to a broader definition of the esports industry, this amount could even be estimated at $24.9 billion in 2019 (Anh et al., 2020). Despite being showcased on the sidelines of the 2018 and 2020 Olympic Games and at the 2022 Asian Games, the practice of esports raises questions. While most esports involve the body and very fine motor skills (Besombes, 2018; Hilvoorde & Pot, 2016; Pluss et al., 2020), as players are required to press the correct keys on the control device (console controller, joystick, keyboard, mouse, etc.) at the right time within precise time frames, players most often play while seated (Besombes & Maillot, 2018) in front of a screen for hours at a time.

The consequences of a sedentary lifestyle and inactivity are current public health problems (Illivi & Honta, 2020). Sedentary behavior is typified by low energy expenditure (less than or equal to 1.5 metabolic equivalents of task [METs] in a seated or prone position [excluding sleep]; Tremblay et al., 2010). Inactivity is characterized by insufficient duration, frequency, and level of physical activity (PA), i.e., below a certain threshold. This threshold determines how much PA is considered enough, and therefore whether an individual is active or inactive. For adults aged 18 to 65 years, the threshold recommended by the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the American College of Sports Medicine (ACSM) is 150 minutes of moderate-intensity PA (e.g., 30 minutes per day, five days per week) or 75 minutes of vigorous-intensity exercise per week. Several studies show that many people fail to meet these recommendations (Kohl et al., 2012). In 2016, the global prevalence of insufficient PA was 27%, while for adolescents it was 81% (Guthold et al., 2018, 2020). These shortfalls are associated with adverse health effects, as physical inactivity is considered the fourth most important risk factor for mortality worldwide (Kohl et al., 2012). In addition to its negative effects on mental health and quality of life, physical inactivity is a factor in cardiovascular disease, type 2 diabetes, breast and colon cancer, and reduced life expectancy (Lee et al., 2012).

In this context, public authorities have many concerns about the potential negative effects of esports on the health of players (Wattanapisit et al., 2020). Although many studies exist on the physiological effects of video gaming on health, only a few have focused on competitive practice, which seems to have its own specificities. Several scientific studies criticize the lack of data on the PA of esports players, as well as on other factors linked to lifestyle (Kelly & Leung, 2021; Yin et al., 2020). This scarcity limits our knowledge of how to promote health. Data also seem to be lacking on specific esports practices, linked in particular to the level of expertise (amateur, professional, etc.) and/or to the types of games played.

However, researchers suggest that esports may lead individuals to adopt a healthier lifestyle themselves or act as a lever for authorities to promote this healthy lifestyle (Chan et al., 2022; Ketelhut et al., 2021; Micallef et al., 2022; Polman et al., 2018; Schary et al., 2022). For example, some hypothesize that participation in certain esports (e.g., sports simulations) could motivate players to engage in real PA (Adachy & Willoughby, 2015; Jenny & Schary, 2014). On the other hand, several studies have recently highlighted the positive effect of PA on in-game performance (De Las Heras et al., 2020; Toth et al., 2020). Following this state of research on the topic, several questions remain: Are esports players inactive? Does engaging in this sedentary competitive practice push players to abandon PA or to also engage in physical exercise?

When this work was initiated, only one systematic review on this subject had been published (Lam et al., 2020). The review was published in 2020 and included six studies. We were aware that new studies had appeared shortly afterwards that provided a better understanding of the phenomenon. During the course of our work, another systematic review was published, focusing on the impact of esports and online video games on the lifestyle behaviors (including PA) of young people (Chan et al., 2022). However, although the title refers to "the impact of esports," only three of the 36 studies included in the review actually refer to esports. Finally, a scoping review aiming to identify the influences of PA and dietary behaviors in emerging adults was also published during this time (Micallef et al., 2021). Of the 112 articles identified in this review, seven refer to the influence of online video games on PA. However, none of these seven articles concerns the specific practice of esports. Thus, these other reviews confirm the relevance of our own research work. Micallef et al. (2022) conducted another scoping review, identifying 23 health behavior influences in online gaming among emerging adults. These influences included family, virtual peers, characters, guild, console manufacturer or brands, esports events, esports organizations, and esports athletes. However, the impact, positive or negative, of these influences has not yet been studied.

Objectives

This systematic review of the literature on the links between esports and PA aims to identify the main findings to date, the questions that remain open, and the studies that need to be conducted in the near future to fill the knowledge gaps on the subject. The three main questions guiding this review were: (1) What are the PA levels of

esports players? (2) Do data exist on the influence of participation in esports on players' PA? (3) What future research questions can be derived from these results, and what studies should be conducted in the near future to fill the knowledge gap on this topic?

Method

Design and Protocol

The systematic review method provides a review of the existing literature that minimizes bias. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which allow for the reproducibility of work and help authors transparently report their findings (Page, McKenzie, et al., 2021; Page, Moher, et al., 2021).

Eligibility Criteria

To clearly delineate our scope and answer our research questions, studies had to meet the predetermined selection criteria of Population, Intervention, Comparison, Outcome, and Study Design (PICOS) to be included:

- Population: The studies had to contain samples of healthy individuals over the age of 12 years.
- Intervention: Participants in the studies had to be competitive video game players participating in ranked games and/or online or offline competitions at different levels of engagement in the esports practice (e.g., recreational, amateur, or professional). Studies involving exergames were excluded because exergames induce higher energy expenditure, are not sedentary games, and are very rarely played competitively. Studies involving video games played recreationally, outside of a competitive setting, were also excluded.
- A comparison group was not required.
- Outcome: Studies had to report data on PA levels and/or influences on PA.
- Study Design: Studies had to be published (and peer-reviewed) in English and provide empirical data using quantitative, qualitative, or mixed methodologies.

Information Sources and Searches

To find all studies in the scientific literature related to the competitive practice of video games and PA that met our eligibility criteria, the PubMed database and three additional databases (Google Scholar, ResearchGate, and ScienceDirect) were searched, with no publication date restriction. Given the plurality of terms used to refer to esports in the literature, the search included several keywords: (electronic video game* OR competitive video game* OR pro game* OR professional video game* OR online game* OR sport video game* OR esport*) AND (sedentary OR physical activity OR physical inactivity OR inactivity) NOT (esporte OR esportiva OR esportivo). The exclusion of the term "esporte" avoided a profusion of studies written in Spanish referring to sport. This search strategy was developed in PubMed and then adapted to Google Scholar, ResearchGate, and ScienceDirect. Furthermore, the search comprised reference list searching, citation searching, and hand searching. Although the initial search started on May 15, 2021, data collection was extended to August 1, 2022. Until this date, we maintained a scientific watch through manual searches and searches of the studies' citation lists. The last study included was dated February 16, 2022, and unless we are mistaken, this work includes all eligible studies published before August 1, 2022.

Data Extraction Process

The procedure was performed using only free tools: the bibliography management software Zotero (5.0.84) and Microsoft® Excel (Mateo, 2020). Following the identification and deletion of duplicates, the articles were selected based on their title and abstract. Five exclusion criteria were retained and scored from 1 to 5:

- Criterion 1: It is not esports.
- Criterion 2: It is not about PA.
- Criterion 3: There is no empirical data input.
- Criterion 4: The population is not healthy or is under 12 years of age.
- Criterion 5: The study is unpublished.

Articles that appeared to meet the inclusion criteria, or for which there was doubt due to a lack of information, were exported for an eligibility check. Eligible articles were then read in their entirety for inclusion in the review or excluded based on the criteria. This method achieved our objective while minimizing the risk of error.

Risk of Bias

To assess the methodological quality of quantitative studies, we used the adaptation of the Newcastle-Ottawa Scale (NOS) adapted for cross-sectional studies (Herzog et al., 2013), which is described in the supplementary material. Studies are scored out of 10. For qualitative studies, the methodological checklist "Critical Appraisal Skills Program (CASP): Qualitative Research," which provides key criteria relevant to qualitative research studies, was used. A score out of 10 was also obtained.

Synthesis of Results

To answer our research questions and clearly present the different results, we first described the geographical locations of the studies, the sociodemographic characteristics of the participants (gender and age), and the types of esports (games played and expertise levels). This allowed us to later examine whether these variables affected players' PA levels. We also documented the purpose of the studies, the methodologies and tools used to measure PA levels (and/or the influence of esports participation on PA), and the quality of the evidence. Results and data on PA levels and on the influence of esports participation on PA were summarized. When possible, we used the WHO recommendations of 150 minutes of activity per week as the standard to determine whether the majority (or average) of esports athletes in the studies appeared to be active or inactive. We presented the results for the full sample of included studies. We also presented the results for each level of expertise/esports player population, as well as for each game/game type and geographic region, when possible. Given the relative heterogeneity of the studies, no meta-analysis was undertaken.

Results

Study Selection

Searches on the PubMed, ScienceDirect, Google Scholar, and ResearchGate databases using key words identified 1,850 studies. Following the removal of duplicates, 1,785 studies remained. After reading the titles and abstracts, 1,755 studies were excluded. Thirty articles were then read in their entirety to assess eligibility. Eighteen of these 30 articles were excluded: three were not esports related, two were not PA related, 11 did not provide empirical evidence, and two were not published. Six additional studies were identified by checking the citation lists of the included articles. In the end, 18 studies were included in the review, with data from 7,442 participants. The process of selecting the studies is summarized in Figure 1.

Study Characteristics

These 18 studies were published between 2016 and 2022. Eight of the studies (2, 4–5, 8, 10, 13, 16, 18) had relatively small sample sizes (i.e., $n < 70$), and six studies (1, 11–12, 14–15, 17) had large sample sizes (i.e., $n > 720$).

Thirteen studies targeted a population of esports players from a specific country, such as Saudi Arabia (1), the United States (2, 4–5, 13, 18), Denmark (9), Indonesia (10), Portugal (11–12), Germany (14–15), or Malaysia (16). One ($n = 1$) study targeted and compared athletes from three different countries: South Korea, the United States, and Turkey (3). Four ($n = 4$) studies did not target any specific geographical area and included participants from 65 different countries in Latin America and Europe (17), or from mainly Europe and North America (6–8).

Most studies ($n = 11$) surveyed high-level athletes and/or athletes supervised by professionals within a structure (club, college, etc.). Five ($n = 5$) studies targeted college players (2, 4–5, 13, 18). Three ($n = 3$) studies focused on professional and/or high-level athletes (6–8). One ($n=1$) reported data from club members who represented their country in international competitions (3). One ($n = 1$) targeted the top 50 players of a national competition (10).

Finally, the remaining seven ($n = 7$) studies targeted or distinguished between different levels of practice within their samples. Two ($n = 2$) focused on players of different levels participating in Portuguese Football Federation competitions (11–12). One ($n = 1$) focused on all esports players in Malaysia who participated in ranked games, national competitions, or international competitions (16). One ($n = 1$) distinguished between recreational players and players under contract participating in competitions (1). Another ($n = 1$) differentiated players according to their rank in their preferred games (17). The last two distinguished between occasional, regular, amateur, and professional players (14–15). These last four ($n = 4$) studies separated players of different levels into different outcome groups, while the first three ($n = 3$) did not distinguish between different levels of practice.

Only three ($n = 3$) studies specifically targeted players of a single game or type of game. Two of these targeted virtual football players (11–12), and one ($n = 1$) targeted players of a multiplayer online battle arena (MOBA) game

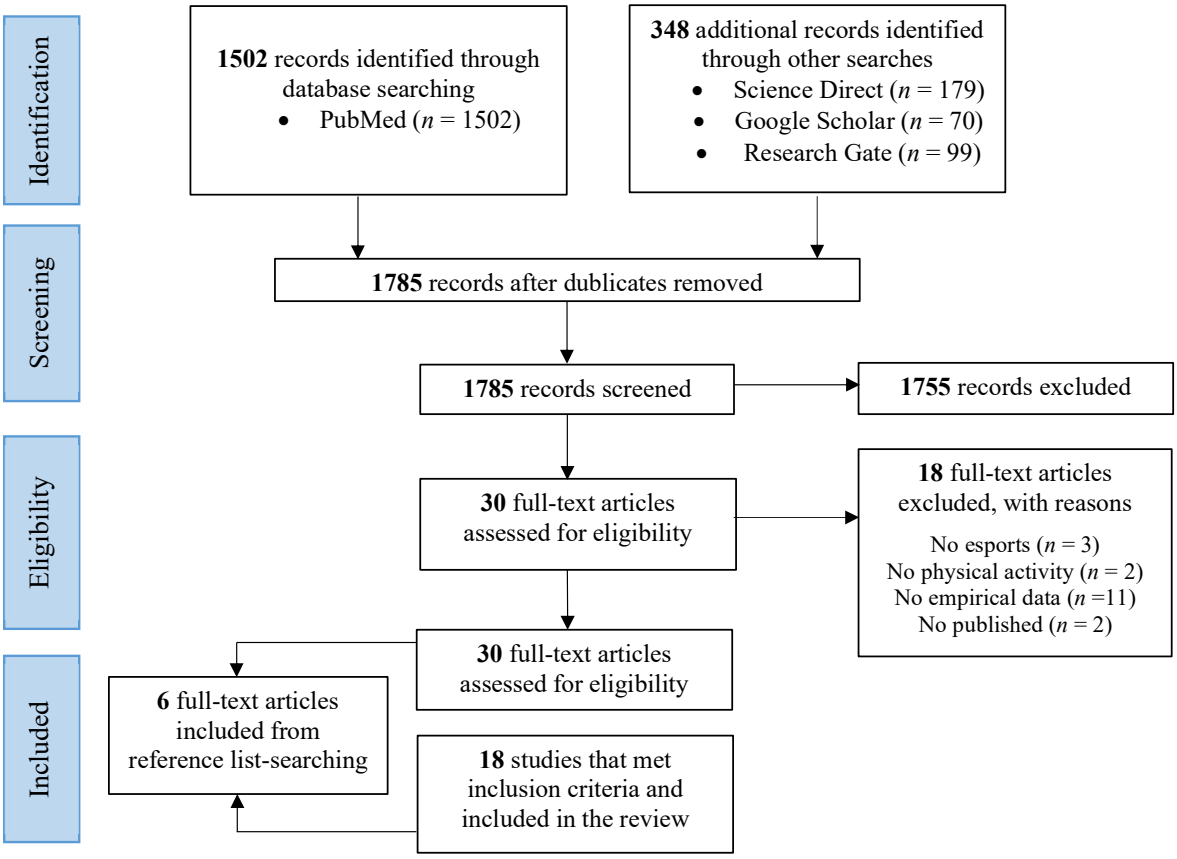

Figure 1. PRISMA flowchart for the study selection process

(10). One (n = 1) study differentiated the results according to the individual or collective nature of the game (player vs player or team vs team; 7). Eight (n = 8) studies recorded the games played, but did not differentiate the results according to the game played (5–9, 14–15, 17). Finally, six (n = 6) studies provided no information on the types of games played (1, 3–4, 13, 16, 18).

Male subjects were overwhelmingly represented in all studies. In eight (n = 8) studies, 100% of the subjects were male (2–6, 8, 10, 13). In only three studies were more than 10% of the subjects female (1, 16–17). Most participants in the studies were young adults aged between 18 and 25 years.

Finally, 17 (n = 17) studies aimed, among other things, to assess the PA levels of athletes (1, 3–18). Some had other objectives, such as implementing a health management model or assessing body composition, sedentary behavior, training habits, health-related lifestyle habits, common health issues, prevalence of MSK pain, the influence of player rank on health behaviors, the relationship between playing time and health behaviors, or the relationship between esports athletes' PA and other variables. The last study (2) aimed to describe the physiological and perceptual responses in a live esports tournament, but also measured PA to characterize the participants.

Methods of Included Studies

The studies used different methodologies to measure the athletes' PA. The study by Kari et al. (2019) was qualitative and used interviews. The study by DiFrancisco-Donoghue et al. (2020) was a cohort study. Sixteen (n=16) studies were cross-sectional and provided quantitative data. Only Bayrakdar et al. (2020) and DiFrancisco-Donoghue et al. (2020) used objective data (number of steps) to quantify PA. Bayrakdar et al. (2020) used self-reporting to obtain step count data and evaluated the athletes' PA (or inactivity) based on the graded step index introduced by Tudor-Locke et al. (2011). DiFrancisco-Donoghue et al. (2020) used a Fitbit activity tracker worn on the wrist to measure steps and compared the activity of athletes with age-matched non-athletic controls. These two studies also included data self-reported via questionnaires, as did all of the other 15 (n = 15) quantitative studies. In 14 studies (n = 14), the questionnaires were online. Eight (n=8) of these studies (1, 6, 9–13, 16) used the International

Physical Activity Questionnaire (IPAQ), a validated measurement tool, to classify participants into three different groups according to their PA (i.e., high, moderate, or low). The PA questionnaires of the other nine (n=9) studies were constructed by their authors. The studies of Pereira et al. (2019, 2021) were inspired by and used the Kari and Karhulahti (2016) questionnaire in their own questionnaires. Thus, in addition to references to the step scale and the IPAQ, the authors referred mainly to the WHO adult recommendations of 150 min/week.

Risk of Bias

The overall quality ratings for each study range from 1 to 7, with a mean of M = 4.77. Except for four (n = 4) studies (2, 4, 16, 18), all of the works provided satisfactory levels of evidence according to this scale. Most studies lost points due to the use of self-reporting measurement tools. Other biases and limitations, which may not be apparent from these scales, are highlighted below.

Physical Activity Level

In three (n = 3) studies, the majority (4, 17) or average (5) of esports players did not reach the WHO recommendations and appeared to be inactive. In another (n = 1; 3), they appeared on average as "low-active" according to the graduated step index of Tudor-Locke et al. (2011). On the contrary, in 13 (n = 13) studies, the majority (1, 6–8, 11–16) or average (2, 9–10) of esports players exceeded the WHO recommendations and appeared to be active.

Bayrakdar et al. (2020) and DiFrancisco-Donoghue et al. (2020) reported the average step counts of 6,646 ± 3,400 and 6,040.2 ± 3,028.6, which classified the players as "low active." According to DiFrancisco-Donoghue et al. (2020), esports players were significantly less active than non-athletes ($p = 0.04$). The other study by DiFrancisco-Donoghue et al. (2019) reported that 40% did not participate in any form of PA. Finally, Trotter et al. (2020) showed that as a group, 80.3% of the esports players in the sample did not meet the WHO guidelines.

Still, the majority or average of esports players appeared active in 13 (n = 13) studies. Kari and Karhulahti (2016) reported that 88.7% of the professional and elite esports athletes in their sample engaged in PA, and that those over 18 years of age engaged in three times the WHO daily PA recommendations. The eight (n = 8) studies using the IPAQ showed that the majority or average of players were included in the high (6, 9–13, 16) or moderate (1) PA level category. According to the studies by Rudolf et al. (2019, 2022), 66.9% and 80.5% of the samples exceeded the health guidelines. Details of the results are available in Table 1.

The players in the studies on Saudi Arabia (1), Denmark (9), Indonesia (10), Portugal (11–12), Germany (14–15), and Malaysia (16) appeared to be active. Kari and Karhulahti (2016), on the other hand, reported no difference in the PA scores of high-level athletes in North America and Europe ($p > 0.05$). However, the study by Bayrakdar et al. (2020) that differentiates esports athletes from three countries reported that American players appeared less active than Turkish and Korean players ($p < 0.05$). The two studies by DiFrancisco-Donoghue et al. (2019, 2020) that surveyed college gamers in the United States also found that esports players were inactive. However, the American (high-level) subjects in the studies by Roncone et al. (2020) and Kari and Karhulahti (2016) appeared to be active.

The virtual football players in the Portuguese Football Federation (FPF) appeared to be very active (Pereira et al., 2019, 2021), as did the MOBA players in Indonesia (Paramitha et al., 2021).

The levels of PA were not always the same depending on the participants' level of expertise in esports. Trotter et al. (2020) showed that the top 10% of athletes were significantly more active than the other 90% ($p < 0.05$), and that the players' in-game rank was positively associated with the number of days they were physically active per week ($p < 0.01$). The studies by Kari and Karhulahti (2016), Kari et al. (2019), Giakoni-Ramírez et al. (2022), and Paramitha et al. (2021) targeting high-level and/or professional players reported that these players were very active. On the other hand, players who represented their countries in international competitions (3) and collegiate athletes (4–5), who are assumed to have a high level of expertise, did not appear to be very active, bringing into question the idea that high-level esports players are more active.

AlMarzooqi et al. (2022) and Rudolf et al. (2019, 2022) also found no significant difference in PA levels between paid competitive esports players and recreational players ($p = 0.898$), or according to the players' level of expertise ($p > 0.05$). All the players in their samples were active.

Sixteen (n = 14) studies did not provide data on the nature of the PA practiced (1–6, 9–10, 13, 15–18). In three (n = 3) studies, information was provided on the supervision and planning of PA (7, 11–12). According to these studies, 70.4%, 51%, or 60% of players would plan their own exercise. For 4.4%, 16%, or 18.84%, planning was done by an e-sports coach, while for 5.2% or 13.49%, it was done by a personal trainer (7, 11–12). Through their interviews, Kari et al. (2019) reported that some players jogged, played football in a club, or did weight training at home or in a gym. Rudolf et al. (2019) showed that 36% of their sample practiced fitness, 28.4% cycling, 28.3%

Table 1. Summary of included articles

Study	Location; year	Study aims	Sample size (% males)	Age; location of participants; mean (SD)	Level and esports practiced	Study design; method overview	Results; mean (SD)	Inactive?; findings	NOS or CASP
(1) AlMarzoo-qiet al., 2022	Saudi Arabia; 2021	To determine the prevalence and relationship between symptoms of nomophobia, psychological aspects, insomnia, and PA of esports players in Saudi Arabia	893 (76.6%)	Age (years) = 18-25 (n=501), 26-30 (n=207), ≥31 (n=185)	Esports players (competition, with work contract or salary; n=216); recreational gamers (n=677); nr	Cross-sectional; self-reported electronic questionnaire; IPAQ	Low PA (n=25), moderate PA (n=633), high PA (n=235); both groups had a similar percentage of participants with vigorous/ moderate/low PA	Active; 26.3% were included in the high PA level category, 70.9% moderate level, 2.8% low level; no significant difference in PA levels between paid competitive esports players and recreational players (p=0.898)	4
(2) Andre et al., 2020	USA; 2018	To describe the physiological and perceptual responses in a live collegiate esports tournament	14 (100%)	Age (years) = 19.8 (1.0)	University of Mississippi Esports team; Overwatch (n=4), Super Smash Bros (n=3), RL (n=2), CS (n=2), CoD (n=3)	Cross-sectional; self-reported questionnaire	PA (h/week) = 3.9 (2.4); PA (days/week) = 3.5 (2.2)	Active	3
(3) Bayrakdar et al., 2020	Turkey, South Korea, USA; nr	To determine the effect of esports on PA level and body composition	137 (100%)	Age (years) = 19.92 (2.21); Turkey (n=27), USA (n=63), South Korea (n=47)	Licensed in a club and representing their country in international competitions; nr	Cross-sectional; self-reported data received by email from esports clubs	PA steps = 6,646 (3,400); Turkey PA steps = 7,909 (2,982), South Korea PA steps = 7,785 (3,018), USA PA steps = 5,255 (3,350)	"Low-active"; there were no significant relationships between playing time and BMI and the number of PA steps (p>0.05). However, as playing time increased, BMI increased and the number of PA steps decreased	5
(4) DiFrancisco-Donoghue et al., 2019	USA, Canada; nr	To determine the lifestyle/ health habits of college athletes; report on common health issues that arise in competitive gaming and present a health care model for institutions to help them create protocols to prevent and treat common health issues in esports athletes	65 (100%)	Age (years) = 18-22; eight different universities in the USA	Collegiate esports players; nr	Cross-sectional; self-reported electronic questionnaire	40% did not participate in any form of PA	Inactive	1
(5) DiFrancisco-Donoghue et al., 2020	USA; nr	To examine the activity levels, BMI, and body composition of college esports players compared with age-matched controls	24 (100%); esports players (n=13) & controls (n=11)	Age (years) = 20.2 (1.7; esports), 19.2 (1.3; controls)	Collegiate esports players who were members of the American Collegiate East Coast Esports League; MOBA and FPS. High platinum/low diamond ranked team in Overwatch and Platinum1/Diamond4 for MOBAs	Cohort; Fitbit Charge activity tracker worn 24 h/ day for 14 days; self-reported questionnaire	Step count 6,040.2 (3,028.6) vs 12,843.8 (5,661.1); PA (days/ week) 1.7 (1.9) vs 4.8 (1.2); Exercise (min/session) 39.5 (40.4) vs 56.7 (26.8)	Inactive or "low-active"; collegiate esports players were significantly less active than non-esports players (p=0.04)	6

Study	Location; year	Study aims	Sample size (% males)	Age; location of participants; mean (SD)	Level and esports practiced	Study design; method overview	Results; mean (SD)	Inactive?; findings	NOS or CASP
(6) Giakoni-Ramírez et al., 2022	European and Latin American countries; 2021	To analyze the relationship between PA levels and motivational orientations in an international sample of professional esports players	260 (100%)	Age (years) = 21.30; Spain (n=56), Germany (n=43), Sweden (n=44), Chile (n=23), Argentina (n=26), Brazil (n=42), Mexico (n=26)	Professional players; LoL (n=116), CS (n=86), Hearthstone (n=6), CoD (n=18), FIFA (n=7), Clash Royale (n=22), RL (n=5)	Cross-sectional; self-reported electronic questionnaire; IPAQ	Europe PA (METs) = 2,533.23 (2,017.71), Latin American PA (METs) = 2,428.55 (1,437.69)	Active; 48.5% were included in the high PA level category, 44.2% moderate level, 7.3% low level; extrinsic and intrinsic motivation were inversely correlated with energy expenditure (r=-0.158; r=-0.174)	5
(7) Kari & Karhulahti, 2016	Europe, North America, and others; 2015-2016	To study the training habits of elite e-athletes, with a particular focus on exercise habits	115 (97.39%)	Age (years) = -19 (n=50), 20-24 (n=49), 25-29 (n=12), 30- (n=4); Europe (n=63), North America (n=35), other (n=11)	Professional players (n=31), high-level players (n=84) ranked in the best of their games; PvP games (n=31), team games (n=78), N/A (n=6); CS (n=51), SC2 (n=15), DOTA 2 (n=14), LoL (n=12), other (n=23)	Cross-sectional; self-reported electronic questionnaire	PA (h/day) = 1.08 (0.83); 88.7% of professional and elite e-athletes practiced PA; 81.7% reported having a PA program; 70.4% planned their own PA, 5.2% planned by personal coach, 4.4% by team coach; 18.3% had no training plan; main reason for physical training: physical health (47%), physical appearance (17.4%), to be more successful in esports (8.7%), physical capacity (7.0%), fun or enjoyment (5.2%)	Active; elite e-athletes aged 18 and older engaged in more than three times the WHO daily activity recommendation	7
(8) Kari et al., 2019	USA, Europe; 2017-2018	Extensively revise the authors' previous study (2016) on the training routines of professional and high-level esports players, with an additional focus on their PA	7 (100%)	Age (years) = 18-25; North America (n=2), Europe (n=5)	North American TOP 200 LoL players studying at an American university on an esports scholarship (n=2), international competitors on Hearthstone (n=1), Tekken (n=1), and DOTA (n=2), challenger on LoL (n=1)	Qualitative interviews	Roughly an hour of PA per day; different types of PA: running, soccer, weight training, walking; they believed PA to be useful against injuries, but practiced mainly for health benefits (to boost concentration, mood, and energy); stretching against pain; no PA plan; coaches and their teams recommended 1-2h of PA per week; difference in training between Hearthstone players and others	Active; players believed in the benefits of exercise, but coaches and their teams sometimes thought it to be of little importance; there was a discrepancy between the players' attitudes towards exercise and the amount of exercise they did; PA seemed largely unstructured and unsystematic; the reasons for practicing PA were more related to an awareness of the benefits of a healthy lifestyle than to a desire to enhance esports performance	7

Study	Location; year	Study aims	Sample size (% males)	Age; location of participants; mean (SD)	Level and esports practiced	Study design; method overview	Results; mean (SD)	Inactive?; findings	NOS or CASP
(9) Lindberg et al., 2020	Denmark; 2019	To investigate (1) the prevalence of MSK pain, (2) the association between MSK pain and esports-related training volume, and (3) the association between MSK pain and PA levels	188 (97.9%)	Age (years) = 17.1 (2.3); Denmark	Structured esports athletes (training with coach) in an educational institution (n=146), community-based team (n=30), pro-team (n=4), or other (n=8); CS (n=109), LoL (n=51), other (n=28)	Cross-sectional; self-reported electronic questionnaire; IPAQ	MSK pain group PA (METs min/week) = 3,722.4 (3,667.3); no MSK pain group PA (METs min/week) = 3,641.3 (4,563.1)	Active; athletes were included in the high PA level category; there was no significant correlation between MSK pain and PA levels (p=0.906)	7
(10) Paramitha et al., 2021	Indonesia; 2019	To determine the PA level of Indonesian professional athletes, to gather preliminary data for recommendations to major esports organizations or sports policymakers in future esports development efforts	50 (100%)	Age (years) = 21.5 (1.01); Indonesia	Players qualified for the final round (top 50) of the national competition, the 2019 Esports Presidential Cup; MOBA	Cross-sectional; self-reported questionnaire; IPAQ	PA (METs min/week) = 3,120.2 (24.3)	Active; players were included in the high PA level category	6
(11) Pereira et al., 2019	Portugal; nr	To assess the PA and sedentary behavior levels of e-athletes participating in FPF esports competitions	721 (99%)	Age (years) = 24 (6); Portugal	Players participating in FPF esports competitions; Virtual Football	Cross-sectional; self-reported electronic questionnaire; IPAQ	PA (METs) = 4,332 (IQR=4,673); 51% planned their own physical training; 16% had PA planned by their esports team coach; main reason for physical training: health (32%), physical capacity (24%), esports performance (6%)	Active; 73% were included in the high PA level category, 15% moderate level, 12% low level	4
(12) Pereira et al., 2021	Portugal; 2018	To conduct a preliminary assessment of the PA levels, sedentary behavior, and physical training habits of adult virtual soccer players in Portugal	926 (98%)	Median age (years) = 22 (IQR=8); Portugal	Players participating in FPF esports competitions, from recreational to professional; Virtual Football	Cross-sectional; self-reported electronic questionnaire; IPAQ	Median PA (METs) = 5,625 (IQR=4,911); 60.0% planned their own PA, 18.84% planned by team coach, 13.49% by personal coach; main reason for physical training: physical health (66.7%), physical capacity (49.53%), fun or enjoyment (41.40), physical appearance (40.47%), to be more successful in esports (6.05%)	Active; 84.53% were included in the high PA level category; 87.07% met WHO recommendations	6
(13) Roncone et al., 2020	USA; nr	To analyze the relationship between the PA and mental toughness of esports athletes	34 (100%)	Age (years) = 20.02 (1.46); USA	Collegiate esports players from one large major NCAA Division I public university	Cross-sectional; self-reported questionnaire; IPAQ	PA (days/week) = 5.8; PA (min/day) = 69; n=33 (97%) engaged in vigorous PA for at least 2 days and up to 7 days per week	Active; 88% met WHO standards; moderate and vigorous PA seemed to be associated with higher levels of mental toughness	6

Study	Location; year	Study aims	Sample size (% males)	Age; location of participants; mean (SD)	Level and esports practiced	Study design; method overview	Results; mean (SD)	Inactive?; findings	NOS or CASP
(14) Rudolf et al., 2020	Germany; 2018	To assess the demographic characteristics and health behaviors of video game and esports players; possible associations between video game time and health behaviors were also examined	1,066 (91.9%)	Age (years) = 22.9 (5.9); Germany	Professional players (n=14), former professional players (n=33), amateurs (n=355), regular players (n=577), occasional players (n=87); CS (n=522), LoL (n=157), PUBG (n=51), Fortnite (n=50), FIFA (n=45), Dota 2 (n=43), Overwatch (n=24), R6 (n=21), RL (n=19), WoW (n=12), other (n=122)	Cross-sectional; self-reported electronic questionnaire	N=713 (66.9%) engaged in moderate to vigorous PA for more than 2.5 h/week; 57.5% of the players who participated in tournaments and official leagues engaged in structured training; they believed good physical condition had very positive (32.2%) or positive (48.1%) effects on in-game performance	Active; no statistically significant or relevant association found between video game time and sleep parameters, PA, and fruit and vegetable consumption (rho<0.10)	6
(15) Rudolf et al., 2022	Germany; 2019	To investigate the media usage, sleep behavior, stress, and well-being of video game and esports players and the association with health	1,038 (91.2%)	Age (years) = 23 (5.4); Germany	Professional players (n=26), former professional players (n=36), amateurs (n=282), regular players (n=545), occasional players (n=149), tactical shooters (n=581), MOBA (n=197), sport and racing simulations (n=90), battle royales (n=58)	Cross-sectional; self-reported electronic questionnaire	N=819 (80.5%) engaged in PA for more than 2.5 h/week; PA (h/week) = 8.8 (10.7); professional PA (h/week) = 7.3 (7.7); former professional PA (h/week) = 10.3 (13.2); amateur PA (h/week) = 8.7 (9.6); regular PA (h/week) = 9.0 (11.4); occasional PA (h/week) = 8.5 (9.9)	Active; esports players showed sufficient general health and had predominantly positive health behaviors; no statistically significant difference in PA levels between groups of players at different levels (p>0.05)	6
(16) Seng et al., 2021	Malaysia; nr	To study the common health issues among esports players	69 (86%)	Age (years) = 18-21 (n=9), >21 (n=60); Malaysia	Ladder/ranking players (n=37, 53.6%), national tournament players (n=26, 37.7%), world tournament players (n=6, 8.7%); nr	Cross-sectional; self-reported electronic questionnaire; IPAQ	nr	Active; 60.9% (n=42) were included in the high PA level category	3
(17) Trotter et al., 2020	65 countries; nr	To investigate the association between obesity, self-reported PA, smoking, alcohol consumption, and perceived health in esports players and the influence of player rank in the game	1,772 (87.2%)	65 countries; USA (n=290), Australia (n=180), Canada (n=75), Germany (n=41), UK (n=26)	Top 10% in-game rank (n=124), 80-89% top in-game rank (n=97), 70-79% top in-game rank (n=102), 0-69% top in-game rank (n=360); 5 esports	Cross-sectional; self-reported electronic questionnaire	Rank 0-69% PA (days/week) = 2.30 (1.98); rank 70-79% PA (days/week) = 2.72 (2.25); rank 80-89% PA (days/week) = 2.47 (2.23); top 10% PA (days/week) = 2.81 (2.09)	Inactive; 80.3% did not meet the WHO recommendations; players' in-game rank is positively associated with the number of days they were physically active per week (p<0.01); top 10% in-game rank were significantly more active than the remaining 90% of esports players (p<0.05)	5

Study	Location; year	Study aims	Sample size (% males)	Age; location of participants; mean (SD)	Level and esports practiced	Study design; method overview	Results; mean (SD)	Inactive?; findings	NOS or CASP
(18) Zwibel et al., 2019	USA; nr	To understand the lifestyle behaviors, exercise habits, and common injuries of esports players in the collegiate setting	63 (94%)	Age (years): 18-22; eight different colleges and universities in the USA	Collegiate esports players; nr	Cross-sectional; self-reported electronic questionnaire	65% (n=41) PA ≥30 min/day, PA (days/week) = 3 (1.7); 24% (n=15) reported no PA; 64% (n=40) reported being conscientious about exercise	nr	1

nr: not reported; IQR: interval quartile range; IPAQ: International Physical Activity Questionnaire; NOS: Newcastle-Ottawa Scale adapted for cross-sectional studies; CASP: Critical Appraisal Skills Program Qualitative Research; CoD: Call of Duty; CS: Counter Strike; LoL: League of Legends; RL: Rocket League; WoW: World of Warcraft; "active" and "inactive" are defined according to the WHO standard; "low-active" is defined according to the graded step index introduced by Tudor-Locke et al. (2011).

running or walking, 17.6% football, 18.5% other ball sports, 11.6% swimming, 5.7% martial arts, 3.5% athletics, 1.9% yoga/Pilates, and only 16.5% did not practice sports. However, the study did not distinguish between the different activities practiced according to the participants' level of expertise.

Bayrakdar et al. (2020) did not report statistically significant relationships between playing time and BMI and the number of PA steps ($p > 0.05$). However, they noted that as playing time increased, BMI increased and the number of PA steps decreased. Rudolf et al. (2019) found no statistically significant association between playing time and PA (rho < 0.10). Finally, Trotter et al. (2020) found that play time was significantly associated with higher in-game rank ($p < 0.001$), levels of perceived PA ($p < 0.001$), and the number of days players were physically active per week ($p < 0.01$).

Influence of Esports on Physical Activity

None of the included studies provided data on the influence of esports practice on PA. However, five (n = 5) studies provided data on the reasons players may have had for engaging in PA (8–9, 11–12, 14). Rudolf et al. (2020) reported that 32.2% believed that physical fitness had very positive effects on in-game performance, and 48.1% believed it had a positive effect. In the studies by Kari and Karhulahti (2016) and Pereira et al. (2021), 55.6% and 38.66% of the subjects believed that incorporating exercise into their training programs had a positive effect on their esports performance. However, Pereira et al. (2021) also noted that for 45.11%, PA had no effect on in-game performance. Worse, for 4.77%, PA even had a negative effect on performance. Thus, Kari et al. (2019) reported that professional and elite esports players' reasons for exercising so much were not due to their desire to improve their performance in competition, but rather to their awareness of the benefits of a healthy lifestyle. According to Kari and Karhulahti (2016), 47% of the subjects exercised primarily to maintain good health, and 8.7% thought the main purpose of exercising was to become more successful in esports. According to Pereira et al. (2021), 32% and 66.7% of the subjects also did physical training mainly to maintain or improve their physical health, and 6% and 6.1% of the subjects responded that they were active to be more successful in esports. Thus, they mainly perceived improved performance to be a desirable consequence, among many others, of good health. Moreover, the subjects interviewed by Kari et al. (2019) confirmed that, in their opinion, good physical health acquired through exercise improved concentration, mood, and energy levels, which helped them focus during daily training and tournaments.

Other main reasons for engaging in PA were given. According to these studies, 17.4% and 40.47% of the subjects exercised mainly to improve their physical appearance; 7%, 24%, and 49.53% to improve their physical capacities; and 5.2% and 41.40% for fun. In the latest study by Pereira et al. (2021), participants could give more than one answer to the question "What is your main reason for doing physical training?" Some may also have sought to improve their physical appearance to perform better, since 29.6% of the subjects in the study by Kari and Karhulahti (2016) believed that physical appearance could influence the competitive performance of others, and 18.3% reported having been personally intimidated by the physical appearance of an opponent.

On the other hand, according to Kari et al. (2019), the media coverage of professional players who engaged in physical training could also encourage amateurs to engage in PA, as they would mimic their idols. Finally, players

on some teams could be encouraged to engage in PA by their coach (or equivalent); for example, the coach from the study by Kari et al. (2019) recommended 1–2 hours of exercise per week. Despite this, according to the studies, only 4.4%, 16%, and 18.84% of esports players were engaging in PA planned by the team coach; 70.4%, 51%, and 60% planned their own exercise (7, 11–12). In addition, Kari et al. (2019) also noted a discrepancy between some players' positive attitudes towards PA and the exercise they practiced, which remained unstructured and unsystematic.

Discussion

Summary of Evidence

In 13 (n = 13) studies, the majority (1, 6–8, 11–16) or average (2, 9–10) of esports players exceeded the WHO guidelines and could be considered active, while in four studies (n = 4), they did not reach the WHO guidelines and were considered inactive (4–5, 17) or "low-active" (3).

Virtual footballers seemed more active than players of other esports (11–12). This is in accordance with previous studies that showed correlations between playing sports video games and PA (García & Murillo, 2020; Ng et al., 2022). Some authors, for example, have shown that participation in sports simulations (e.g., FIFA Soccer or Madden NFL) can increase engagement in real sports (Adachi & Willoughby, 2015; Jenny et al., 2017; Jenny & Schary, 2014), or have hypothesized that players who engage in virtual football simulations are first and foremost football fans, and only secondarily virtual football fans (Peter, 2007).

High-level esports athletes seemed more active than lower-level players. However, some data showed no correlation between the level of expertise in esports and the level of PA (AlMarzooqi et al., 2022; Rudolf et al., 2019, 2022). Some theoretically high-level players even appeared to be inactive (3–5), while some lower-level players seemed to be equally or even more active (14–15). These results may corroborate the idea that video games and sports are not opposed (Peter, 2007). Nevertheless, data is lacking on players of specific types of games and at different levels to more precisely determine the impact of these variables on players' PA.

Factors other than players' levels of expertise may influence differences in PA outcomes. While playing esports in a structured setting with coaches appears to be associated with higher levels of PA, not all clubs, teams, or universities place the same importance on PA. For example, the studies by DiFrancisco-Donoghue et al. (2019, 2020) and Roncone et al. (2020), which examined samples of college players in the United States, presented conflicting results. Beyond potential differences in the levels of college student athletes (Roncone et al., 2020), these differences were primarily due to the specificities of different institutions which, like professional structures, do not integrate exercise into training in the same way. Esports athletes do not receive the same level of professional support from one college to another in terms of PA (e.g., physical trainers, health staff, sports coaches, PA service, nutritional advice, etc.; DiFrancisco-Donoghue et al., 2019). Instead, some players/university teams may be more community oriented, while others focus more on the competitive aspect (Eckman, 2021).

Furthermore, the methodological tools used in the studies seem to influence their results. Indeed, the only two studies relying on objective measurements of the number of steps to measure esports players' PA concluded that they were "low-active" or inactive (Bayrakdar et al., 2020; DiFrancisco-Donoghue et al., 2020). In contrast, the eight (n = 8) studies using the self-reported IPAQ survey found that the players had mainly high or moderate PA levels (1, 6, 9–13, 16). The questionnaire used by Trotter et al. (2020) showed that participants were very inactive.

Different geographical areas could also explain the differences in results. Players from certain countries appeared to be more active (Saudi Arabia, Denmark, Indonesia, Portugal, Germany, and Malaysia), and those from other countries appeared to be less active (United States). However, some of the data were contradictory and were probably confounded by the influence of other variables on PA levels. Thus, data on populations of esports athletes in specific geographical regions are insufficient to reach a conclusion on this.

Beyond the levels of PA, it seems important to distinguish between the nature of PA and how it is practiced (modalities) according to the different types of players (e.g., level, game, etc.). Indeed, some players seemed to practice PA under the supervision of trainers or exercise professionals (e.g., weight training with a trainer or playing football with a trainer), while others engaged in PA autonomously, structuring their own training (e.g., weight training alone at home or running near their home). Differences can also be observed from one esports team to another: some schedule and supervise their players' exercise, while others do not cover these aspects of training. Thus, professional players would be more likely to be required to engage in PA in a supervised manner within their organization. Some players also engaged in PA in a formal and institutional manner (e.g., playing with a football club within a federation), or in an informal and self-organized manner (e.g., playing street football with friends). Thus, rather

than only being esports players, many of them could be first and foremost football players in their own right within a club. This also raises questions about their motivations to play these specific sports. Many players engage in PA for the intrinsic pleasure they get from it, independently of any esports practice. Others exercise for utilitarian purposes and as a complement to esports to improve their performance in the game. These players would not have the same physical commitment if they were not esports players. These motivations to practice are also questionable for the many players who claim to exercise to maintain and improve their health. Do they want to improve their health because they are aware that the sedentary practice of esports can have harmful effects, or would they also engage in sport to improve their well-being and health if they did not practice esports?

Methodological Limitations

Some of the methodological tools used may have limitations. First, self-reporting is the biggest methodological limitation. These questionnaires are often sent out on the social media of gaming communities (e.g., *Discord*, *Reddit*, or *Twitter*), which leads to self-selection of the subjects who volunteer to answer them. Thus, those who engage in PA might be more inclined to voluntarily respond to a questionnaire assessing their PA levels. The second problem with self-reporting is the definition of the level of esports expertise. Subjects may self-report playing at a high level and exaggerate their level. Finally, subjects may also be led to overestimate their results and their level of PA. It is well known, for example, that individuals under-report their weight and over-report their height and activity level (Sallis & Saelens, 2000) as the result of a social desirability bias (Adams, 2005; Furnham, 1986; Podsakoff et al., 2003). Recall (or memory) biases can also distort results. Respondents may have difficulties recalling all of the PA performed, especially when recall is required beyond 24 hours (Jacobs et al., 1993).

In addition, some of these questionnaires are not standardized and ask subjects about their PA in different ways, which may lead to different results. These questionnaires may also be biased, such as the one by Trotter et al. (2020), which measured PA using the questions "How many days per week do you participate in sport or PA for a total of 30 minutes or more per day?" and "How many days per week do you participate in sport or PA for a total of 60 minutes or more per day?" Only 19.7% of the subjects exceeded 30 min/day of PA five times a week, which led them to conclude that 80.3% did not meet the WHO recommendations. However, in addition to recommending 30 min/day five times a week, the WHO also recommends 150 min/week of moderate-intensity activity. Moreover, their questions do not ask for any details on the intensity of the exercise, despite the WHO considering 75 minutes per week enough to be considered active if the activity is of sustained intensity. Thus, an individual who performs an activity with sustained intensity twice a week for 45 minutes will appear inactive according to the questionnaire in this study, but active according to the WHO. The same applies to an individual who performs moderate-intensity activity for 1.5 hours twice a week.

The objective measurement of steps using a pedometer also has limitations, such as not measuring the intensity of PA and horizontal or upper body movements (Reiser & Schlenk, 2009). For example, the many players who participate in weight training may be able to achieve a significant amount of PA without a significant increase in their number of steps. Furthermore, if the measurement is accurate to 96% above a walking speed of 3 mph (Melanson et al., 2004), the pedometer algorithm, the position of the sensor on the body, or differences in the regularity of walking during different activities can all be sources of error (Mattfeld et al., 2021). We can also question the characteristics of the control group used by DiFrancisco-Donoghue et al. (2020) since the study provided little information about the 11 subjects in this group. According to the Tudor-Locke and Bassett graduated step index, their step counts classified them as "very active," which suggests that these individuals may be very athletic.

Another limitation could be related to the representativeness of the subjects in relation to all esports players. Female subjects were absent in most studies, while 35% of individuals who play esports games (Interpret, 2019) and 5% of professional gamers are female (Hilbert, 2019). The same applies to age: most of the subjects in the studies were between 18 and 25 years old. However, many esports players are children and teenagers under the age of 18. Nevertheless, studying this age group seems to be the most important from a public health perspective, as the literature agrees that this period is decisive for the adoption of health-related behavioral habits later in life. Studying the influence of esports for this age group also seems more relevant because the PA of children and young adolescents is influenced mainly by parental choices (Gatouillat et al., 2020). Beyond that, while a large percentage of esports players are Asian, the studies included in this review mainly targeted European and North American audiences. Finally, some players of specific game genres did not appear to be taken into account (e.g., fighting games and sim racing). Thus, certain populations of players seemed to be absent from these studies.

These different populations of esports athletes of different levels and different games were not always differentiated and compared in the results. The impact of the different games on PA was not investigated. As for differences

according to the level of expertise in esports, only five (n = 5; 1, 7, 14–15, 17) of the seven (n = 7; 11–12) studies that surveyed players of different levels distinguished between them in the outcome groups. Furthermore, the levels of the participants in the studies were not always clear. For example, the group "club players who have represented their country in international competitions" can cover a wide range of levels, as can the group "players who participate in competitions and receive a salary." Therefore, without additional information on these topics, the level of these players is unclear.

Finally, the cross-sectional nature of 16 (n = 16) of the 18 (n = 18) studies also represented a limitation. Because of the cross-sectional design, the direction of causality remains uncertain. Indeed, if playing time is correlated with a decrease in PA, are players inactive because they have a high playing time, or do the players have a high playing time because they are basically inactive? Thus, this cross-sectional observation criterion only allows us to know the PA levels of esports players at a given time, to establish correlations between esports practice (and the different specificities of expertise level and game) and PA. It is also not possible to identify the precise influence of esports on PA levels. Indeed, although esports players are inactive according to these studies, one can imagine that they were as or more inactive before starting to play esports, or that they would be as or more inactive if they did not play esports. Therefore, measuring the influence of playing esports on PA seems relevant.

Influence of Esports on Physical Activity

While some studies have investigated the influence of exergames (Chan et al., 2019; Li & Lwin, 2016; Navarro et al., 2020), augmented reality games such as Pokémon Go (Koivisto et al., 2019; Wong, 2017), or sports simulation games (Adachi & Willoughby, 2015) on PA, we found no studies providing data on the influence of esports on PA. However, several studies have suggested that playing esports can potentially lead to an increased awareness of the importance of PA or be a relevant medium for promoting PA among a young population (Chan et al., 2022; Ketelhut et al., 2021; Micallef et al., 2022; Polman et al., 2018; Schary et al., 2022). There are several reasons why a player might want to exercise: to improve in-game performance, to improve their physical appearance, to reduce or prevent injury and be healthy, or to improve mental toughness. Scientific literature on the effects of PA on esports performance is growing (Kosmina, 2020; Toth et al., 2020). However, according to Kari et al. (2019) and Pereira et al. (2021), esports players engaged in PA more to gain the benefits of a healthy lifestyle than to improve their in-game performance. Some studies on player training have also tempered this idea by showing that most players did not consider physical fitness as a determinant of their performance (Nagorsky & Wiemeyer, 2020; Pereira et al., 2021). Furthermore, awareness of the benefits of PA and a healthy lifestyle is not enough to actually engage in PA. Thus, there could be a gap between the discourse or attitude towards PA and the actual level of PA (Baumann et al., 2022; Kari et al., 2019). Beyond these potential motivations, some players would have no choice but to engage in PA when joining certain teams that place importance on physical exercise in their training. This could become even more pronounced in the future, as the professionalization and sportification of esports means that physical fitness and well-being will become the new norms in the training of esports teams (Pargman & Svensson, 2019). On the other hand, by seeing professionals train physically to perform, some amateurs could also be led to engage in PA to imitate their idols. Finally, PA and esports are far from being incompatible activities: a player motivated by competition may be led to engage in esports and in PA and sport with equal enthusiasm, regardless of their virtual or physical nature.

Measuring the influence of esports on PA requires methodological reflection. Numerous studies, mainly from the social sciences, have focused on the determinants of PA (Gatouillat et al., 2020) and can offer tools to study the influence of esports on physical practice. Some approaches focus on the levers of PA (ecological model [Bauman et al., 2012; Hu et al., 2021; Martins et al., 2015; Moulds et al., 2022; Spence & Lee, 2003] or leisure constraints model [Crane & Temple, 2015; Witt & Dangi, 2017]), while others are more interested in the description of PA paths over time (retrospective or longitudinal methods [Bentzen et al., 2021; Bidart, 2013; Forté, 2006; Lafabrègue, 2020; Gardner et al., 2017; Joncheray et al., 2015]). Depending on the methodologies, these approaches make it possible to describe the phenomenon and/or explain and understand it. Thus, they could allow researchers to describe the influence that esports can have on PA, as well as explain and understand the underlying reasons players engage in, continue, resume, or abandon PA. Based on these different approaches, different quantitative and qualitative methodologies appear to be complementary. Following the example of Schary et al. (2022), we encourage the implementation of longitudinal cohort studies, such as the recent study by Giakoni-Ramírez et al. (2021), which undertakes a one-year follow-up with 53 professional esports players to observe the influence of esports on body composition. Finally, semi-structured interviews appear to be essential for understanding the influence of esports on PA.

Limitations with this Review

The results of this review must be interpreted with caution due to the limitations of our study. The biggest limitation is that the data extraction procedure was not performed by several people independently due to a lack of resources. The same applies to the evaluation of the evidence. Another limitation that can be noted is related to the databases explored. It might have been appropriate to explore databases other than PubMed, Google Scholar, and ResearchGate. However, searching for the articles cited by the studies and the articles that cited the studies greatly reduces this bias. Although English is the universal language of research, the restriction to English-language articles might also be a limitation given the popularity of esports in Asia. Finally, the small number (n=18) of existing and included studies on a topic as complex and multi-faceted as esports (different games, modalities, and levels of expertise) and PA prevents us from establishing meaningful conclusions that could resolve important controversies.

Implications

Further quantitative research with different populations of esports athletes is welcome. These studies should clearly specify the levels of expertise of the subjects and the types of games played. These studies could provide data on a population of players of specific game genres and levels, such as high-level sim racing players or amateur fighting game players. These studies could focus on a specific geographical region or study players from different geographical regions. They might also choose to examine players from different games and of different levels within the same study. It would then be important to differentiate and compare players in the results according to geographical region, game genre, and level to better understand the impact of these variables on PA.

Data on the nature of PA are expected (e.g., running, weight training, football, basketball, cycling, etc.). It would also be interesting to differentiate these activities according to the level and type of sport. Beyond the nature of the activities, details on their modalities are welcome. We invite future studies to characterize the PA of esports players according to whether it is formal (institutionalized practice in a club or sports federation) or free and informal (self-organized; Crosset & Beal, 1997; Travert & L'Aoustet, 2003). Types of PA can also be differentiated according to whether they are supervised by professionals. Finally, physical practice can also be differentiated according to whether players consider it to be independent of their esports practice or a complementary activity (i.e., activity and utilitarian function linked to esports). We imagine that these modalities and motives evolve depending on the level of expertise (e.g., professional or amateur), or even according to the type of game played. Thus, how does a player's level and the game they play influence the nature and modalities of the PA they engage in?

In addition, the inclusion of data on the different relationships between playing time, sedentary time, level of expertise, and PA levels is encouraged.

No measurement tool is perfect; the researcher must be aware of the strengths and weaknesses of each tool. Given the almost exclusive use of self-reported questionnaires and their limitations, we strongly encourage the use of objective measurement tools to assess subjects' activity levels. These have greater validity, greater reliability, and less variability in results (Dowd et al., 2018). While pedometers are a valid and reliable tool that can be used to assess the step counts of subjects (Dowd et al., 2018), triaxial accelerometers could be a good choice for assessing more complex movements (Arvidsson et al., 2019; Trost et al., 2005). However, while they are reliable tools, they also have limitations. Non-ambulatory and static activities such as cycling or weight training will remain poorly distinguished. While accelerometers are equally accurate when worn on the hip or wrist (Migueles et al., 2017; Vanhelst, 2019), we recommend removing accelerometers that are worn on the wrist during periods of playing, as some games require players to make hundreds of small movements per minute with their forearm, wrist, and hand. Since the tool is unable to correctly distinguish between two activities that produce similar total acceleration over time but have different energy costs, it could incorrectly record activity levels (Farrahi et al., 2019). Given these limitations, the use of a heart rate measurement could represent an interesting option for determining energy expenditure, and therefore PA levels. However, the accuracy of the heart rate measurement is limited during low levels of PA because the pulse rate is relatively stable, but the heart is always being used. Heart rate can also be affected by stimuli other than PA, such as medication, medical conditions, or stress levels (Ainsworth et al., 2015; Garet et al., 2005), and therefore by play as well (Valladão et al., 2020). Heart rate monitors and accelerometers would also tend to underestimate energy expenditure (Dowd et al., 2018). Given these limitations, the use of measurement tools that combine both an accelerometer and a heart rate monitor may be a relevant solution (Butte et al., 2012), although these tools tend to overestimate energy expenditure (Dowd et al., 2018). These different tools also have the advantage of objectively and accurately measuring the sedentary levels of players because they allow waking time to be divided into sedentary, light, moderate, and vigorous PA levels.

If studies use questionnaires, we recommend they use validated questionnaires, such as the IPAQ, supplemented with other questionnaires depending on the study objectives. To address social desirability bias and over-reporting of PA levels, the use of a social desirability scale for self-reported data could be considered (Perinelli & Gremigni, 2016).

We believe that the ideal would be a mix of methodologies combining objective quantitative data and qualitative data obtained through interviews. These interviews would identify the players' relationship with their body and their practice, help with understanding their physical habits, provide information about their sports career and experience, and, above all, describe and explain the influence that esports has had on their PA engagement, re-engagement, retention, or withdrawal. Following the conclusions of the scoping review by Monteiro Pereira et al. (2022), with which we agree, we also encourage the conduction of longitudinal studies.

Conclusion

This systematic review allows us to examine the state of research regarding the PA of esports players. The reality of the physical practices of esports players appears so complex and multifaceted that it seems inconceivable to be able to make a general statement on the activity or inactivity of the group of players based on a single study (or even 18 of them). Indeed, wanting to measure the activity of esports athletes in general can be compared to wanting to measure the activity of sports athletes in general. Considering the results, further research is encouraged in both life sciences and social sciences. Therefore, we call for a multidisciplinary approach to obtaining a better understanding of the complex phenomenon of PA. As esports is becoming institutionally structured and recognized in several countries (Abanazir, 2019), and its potential supervision by sports authorities is being discussed (Witkowski, 2022), it seems important to learn more about the relationship between the practice of esports and PA. It seems even more important to know whether playing esports pushes players to engage in PA, resume it, pursue it, or, on the contrary, abandon it. Therefore, following the example of Kari et al. (2019), we believe it is more important to be concerned with the time young players spend training physically rather than the time they spend playing.

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