Original Article

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Assessment of physical activity, exercise capacity and fitness level of the Polish esports players

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Abstract: Professional esport requires players to maintain mental skills at a high level and health-promoting physical condition. The aim of this study was to analyze the levels of physical activity (PA), exercise capacity and physical fitness. The study included 196 male Polish esports players (mean: 20.5±2.4 years), who completed the International Physical Activity Questionnaire (IPAQ) (n= 187), underwent exercise test using a cycle ergometer (n= 141) and participated in selected tests of physical fitness (n= 175). The average total energy expenditure was 1040 MET-min·week^{-1}. The results show that most esports players had low (38%) and moderate (36.4%) levels of PA, and were characterized by an average level of cardiorespiratory fitness (VO_{2max}= 41.92±5.41 mL·kg^{-1}·min^{-1}), and the amount of muscle power generated at the level of AeT (90.98±27.19 W), AnT (149.91± 29.91 W) and VO_{2max} (210.29±42.63 W) was lower than published evidence on physically-active men. Physical fitness of the players was assessed as being satisfactory, but more research needed to clearly confirm this.

Keywords : esports, IPAQ, exercise capacity, total energy expenditure

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INTRODUCTION

Esports is a form of organized competitive video gaming that is gaining increasing recognition and millions of fans worldwide [1,2]. The requirements of esport competitors focus on various cognitive domains (attention, perception, and visuospatial skills) and physical abilities [1,3]. To be successful, esport players must also collaborate and cooperate with other teammates, which in turn requires additional communication skills (oral and verbal) and the expression of these skills in a dynamic and stressful environment. Esports can be divided into different genres (e.g., multiplayer online battle arenas, first-person shooters), which include special skills used in the virtual environment [4]. Previous studies have reported that esport players spend between 5.5 and 14 hours per day in the same seated position [5,6,7]; therefore, there are serious concerns that prolonged time spent in front of a computer screen may have negative physical and psychosocial consequences for these athletes [8].

It has been documented that some health-related behaviors that characterize esport players, such as prolonged sitting [9], sleep restriction and disturbance [10,11], unhealthy dietary habits [12], or video game addiction [13], may negatively affect their health and general well-being.

Some studies have focused on analyzing the level of physical activity (PA) among esport players [9,13-19] and, in the last five years, the most common pain complaints reported by this population [14,20-24]. However, accurate measures of exercise capacity and physical fitness are lacking in the literature, including direct comparisons between esport players at different performance levels (e.g., professional, semi-professional). We addressed these issues, therefore, this study was intended by analyzing the levels of PA, exercise capacity and physical fitness.

MATERIAL AND METHODS

Participants

The study sample consisted of 196 elite Polish male eSports players with at least 2 years of gaming experience (average 6.4±2.6 years). The players trained and participated in tournaments such as Counter-Strike:Global Offensive (CS:GO), League of Legends (LoL), and StarCraft. About 19.9% of the participants had professional experience, defined as receiving financial rewards and specialized training, and the rest were semi-professional (80.1%). Professionals spent more time playing than semi-professionals (6±1.95 $h \cdot day^{-1}$ vs. 4±1.15 $h \cdot day^{-1}$). One third of the group (33.2%) were college players, 22.9% were high school students, and 43.8% of the participants were non-students. The age of the participants ranged from 18 to 29 years (mean: 20.5±2.4 years), with a body weight of 76.3±15.5 kg and a height of 180.3±6.3 cm (Table 1). A body mass index (BMI) was calculated from the height (cm) and weight (kg) data. Based on the WHO recommendation for BMI [kg/m^2] [25], it was found that the majority (62.8%) of esports players had a normal BMI, 20.9% were overweight, 8.7% were underweight, and 7.7% were obese.

Inclusion criteria for the study were: 1) male gender and at least 18 years old; 2) training in a professional or semi-professional team; 3) good general health (no chronic diseases); 4) provide signed written informed consent to participate in this research. The study was conducted in 2020-2022, approved by the Bioethics Committee of the Regional Medical Society in Gdansk (KB-63/22), and conducted in accordance with the Declaration of Helsinki.

Using a cross-sectional design, this study examined the level of PA in 187 esports players, the physical fitness qualities of 141 participants, and 175 players who participated in selected physical fitness tests. For each dependent variable, our sample was divided into professional and semi-professional players for comparative analysis.

Table 1. Characteristics of esports players

Variable		Total (n= 196)	Professional (n= 40)	Semi-professionals (n= 156)
Age (years)		20.5±2.4	21.1±2.6	20.3±2.3
Height (cm)		180.3±6.3	179.7±6.1	180.4±6.4
Weight (kg)		76.3±15.5	76.1±15.6	76.4±15.6
BMI (kg/m^2)		23.4±4.2	23.5±4.1	23.4±4.3
Games	CS:GO	64.3 (126)	32.5 (13)	73.1 (114)
	LoL	35.2 (69)	65 (26)	26.9 (42)
	StarCraft	0.5 (1)	2.5 (1)	0 (0)
Education	Secondary students	22.9 (45)	0 (0)	28.8 (45)
	Collegiate players	33.2 (65)	2.5 (1)	41.0 (64)
	Non-students	43.8 (86)	97.5 (39)	30.1 (47)

Data presented as mean±SD or % (n)

Measures

Assessment of physical activity

The Polish version of the International Physical Activity Questionnaire (IPAQ) was used to assess subjects' PA levels [26]. Participants reported the frequency and duration of sitting, walking, or moderate-to-vigorous physical activity that lasted at least 10 minutes (without interruption) during the previous seven days. Activities lasting less than 10 minutes were not included. Energy expenditure (expressed as MET-min·week^{-1}) was calculated by multiplying the number of activity days per week by the corresponding MET value and the average duration of that activity in minutes. The individual results obtained for all activities performed during the week were summed to obtain the weekly energy expenditure. Each participant was classified into one of three levels based on the following criteria: (1) high: if they met at least one of the following criteria: three or more days of vigorous exercise, including at least 1500 MET-min·week^{-1}, or seven or more days of any combination of activities (vigorous, moderate, or walking) exceeding 3000 MET-min·week^{-1}; (2) moderate: if they met at least one of the following criteria: three or more days of vigorous activity (at least 20 minutes per day), or five or more days of moderate activity or walking (at least 30 minutes per day), or five or more days of any combination of PA (walking, moderate, or vigorous) exceeding 600 MET-min·week^{-1}; (3) low: if they did not meet the criteria for the moderate or high categories.

Assessment of exercise capacity

In order to determine the subject's aerobic capacity (maximum oxygen uptake and the levels of aerobic and anaerobic thresholds), the direct method was used by means of a gradually increasing workload test performed on a Monark 894E cycle ergometer. The test began with a 3-minute warm-up of unloaded cycling and the load was increased by 50 W every 3 minutes until voluntary exhaustion was reached. The cadence was 60 rpm. Heart rate was simultaneously recorded with a pulse oxymeter (Polar Electro, model S410). During the test, oxygen uptake (VO_2), minute ventilation (VE), and heart rate (HR) were recorded every 30 s. Aerobic and anaerobic thresholds were analyzed based on the dynamic changes of respiratory parameters. Overall, the following indicators of exercise capacity were evaluated: maximum oxygen uptake (VO_{2max}), maximum HR (HR_{max}), HR at aerobic threshold (HR at AeT) and anaerobic threshold (HR at AnT), HR recovery time to AeT, power at oxygen threshold (PO at AeT) and anaerobic threshold (PO at AnT), maximum power at VO_{2max} (PO at VO_{2max}), total work (kJ).

Assessment of physical fitness

The physical fitness of the participants was assessed by selected tests from the tests developed by the International Committee on the Standardization of Physical Fitness

Tests (ICSPFT) and the European Fitness Test (EUROFIT) [27]. To assess physical fitness, we performed a series of modified fitness tests: upper body strength/endurance push-ups (bending and straightening arms in support), muscular fitness, trunk abdominal strength (bending forward from lying backward), and grip strength using a dynamometer (Jamar), preceded by a presentation of correct exercise technique and a standardized warm-up. The following criteria were used to evaluate correctly performed exercises 30 or more arm bends (very good); 20-29 arm bends (good), 10-19 arm bends (fair/inadequate), and <10 arm bends (poor). Right and left hand grip strength was referenced to normative values found in the literature. The classification for each age group was adopted: 18-19 years (poor score: <35.7, normal score: 35.7-55.5, strong score: >55.5); 20-24 years (poor score: <36.8, normal score: 36.8-56.6, strong score: >56.6); 25-29 years (poor score: <37.7, normal score: 37.7-57.5, strong score: >57.5).

Statistical analysis

Statistical analysis of the study data was performed using Statistica 12.0 (StatSoft Inc., USA). The characteristics of the group and the results obtained are presented as numerical data (n), percentages (%), descriptive statistics in the form of means ($\bar{x}$), standard deviations (SD), and medians (Me). When there was a large number of variables in the analysis, the results are presented as medians. The dependencies of the variables studied were tested and statistically compared using the Pearson chi-square test of independence (professional vs. semi-professional eSports players). The level of statistical significance was set at $p < 0.05$.

RESULTS

The total energy expenditure associated with sports PA was 1040 MET-min·week^{-1}. Both groups were not statistically different in terms of PA (walking, moderate and vigorous activities). The results of the present study indicate that professionals spent significantly more time sitting than semi-professionals (600 min vs. 400 min, $\chi2 = 60.4$; $p = .04$). A quarter of the participants showed a high level of PA, while 38% of the esports players were characterized by moderate activity and 36.4% by low activity. Among the professionals, the highest percentage were participants with moderate activity (54.1%), while semi-professionals dominated the players with low PA (37.9%) (Table 2).

The relative VO_{2max} in our male sample was 41.92±5.41 mL·kg^{-1}·min^{-1} and showed no difference between semi-professional (41.98±5.50 mL·kg^{-1}·min^{-1}) and professional (41.64±4.91 mL·kg^{-1}·min^{-1}) players. The maximum HR_{max} of the men studied was 191±10 beats·min^{-1} and was similar in each of the study subgroups (191±10 and 192±7 beats·min^{-1}). Subgroup performance on these indices was not significantly different. The maximum power achieved at the VO_{2max} level was 210.29±42.63 W for all players tested and was similar in the semi-professional and professional subgroups, at 210.73±43.20 and 208.15±39.70 W, respectively.

HR values at the AeT level were 146.20±6.94 beats·min^{-1} in all subjects and showed no intergroup differentiation between semi-professional (146.00±7.20 beats·min^{-1}) and professional (147.17±5.38 beats·min^{-1}) players. The relative HR values, expressed in relation to $\%HR_{max}$ at the aerobic threshold level, were 76.47±2.00% among the subjects and were similar in the semi-professional and professional groups, amounting to 76.46±1.97 and 76.53±2.04%, respectively. The mean rate of heart contractions at the anaerobic threshold was 174.16 ± 7.87 beats·min^{-1} for all subjects and was similar in both subgroups (174.03±8.22 and 174.83±5.80 beats·min^{-1}). HR values expressed as % HR_{max} at the were approximately 91.09±1.10% for all subjects and were independent of playing level. Similarly, power values at AnT were similar in both athlete subgroups (149.89±31.20 and 150.04±22.58 W), with mean values of 149.91±29.91 W when data were pooled (Table 3).

Regarding the perception of physical fitness, most participants achieved a very good (45.09%) or good (38.73%) result. However, it is worth noting that among those who performed <10 arm bends, some did not perform a single correct repetition and they accounted for 9.25% of all respondents. On the other hand, more than 94% of the participants obtained a good or very good grade in the forward trunk bending test, and 1.73% of the subjects did not perform any technically correct repetitions (<10 bends) (Table 4). Individual results for the professional and semi-professional subgroups are shown in Table 5.

The grip strength of the study participants was assessed for both the left and right hand as a normative result in comparison to men aged 18-19 years (60% and 61.42%) and 20-24 years (61.42% and 59.34%) (Figure 1). The grip strength of the professional and semi-professional athletes is shown in Figures 2 and 3.

Table 2. Levels of physical activity depending on esports status based on the IPAQ questionnaire

Sport level	Total (n= 187)	Professionals (n= 37)	Semi-professionals (n= 150)	p
Low	36.4 (68)	29.7 (11)	38.0 (57)	0.488
Moderate	37.9 (71)	54.1 (20)	34.0 (51)	0.444
High	25.7 (48)	16.2 (6)	28.0 (42)	0.431

Data are expressed as percentages (n); significant difference between groups p<0.05

Table 3. Physological responses at excercise graded intensity during cycling

Physiological parameters	Total (n= 141)	Professional (n= 24)	Semi-Professional (n= 117)	p
$VO_{2\ max}$ ($mL·kg^{-1}·min^{-1}$)	41.92±5.41	41.64±4.91	41.98±5.50	0.100
VE_{max} ($L·min^{-1}$)	111.66±4.18	111.97± 11.77	111.60±14.62	0.373
HR_{max} ($beats·min^{-1}$)	191.28±9,83	192.38±7.16	191.05±10.28	0.855
PO at VO_{2max} (W)	210.29±42,63	208.15±39.70	210.73±43.20	0.611
HR at AeT ($beats·min^{-1}$)	146.20±6.94	147.17±5.00	146.00±7.20	0.960
% HR_{max} at AeT	76.47±2.00	76.53±2.04	76.46±1.97	0.072
PO at AeT (W)	90.98±27.19	93.03± 26.08	90.56±27.40	0.823
HR at AnT ($beats·min^{-1}$)	174.16±7.87	174.83±5.80	174.03 ± 8.22	0.974
% HR_{max} at AnT	91.09±1.10	90.90±1.03	91.13±1.11	0.223
PO at AnT (W)	149.91±29.91	150.04±22.58	149.89±31.20	0.899
Total Work (kJ)	74.29±28.45	74.67±22.87	74.22±29.46	0.858
HR recovery time to AeT (s)	113.55±33.41	114.33±31.24	113.38±33.83	0.144

Data are presented as mean ± SD; significant difference between groups p<0.05; $mL·kg^{-1}·min^{-1}$ milliliters per kilogram per minute; $L·min^{-1}$ - liters per minute; VO_{2max}- maximum oxygen uptake; VE_{max}- maximum minute ventilation; HR_{max}- maximum heart rate; PO at VO_{2max}- power output at maximum oxygen rate, HR- heart rate, AeT- aerobic threshold, % HR_{max}- percentage of maximum heart rate, PO at AeT- power output at aerobic threshold, HR at AnT- heart rate at anaerobic threshold, % HR_{max} at AnT- percentage of maximum heart rate at anaerobic threshold; PO at AnT- power output at anaerobic threshold.

Table 4. Results of individual fitness tests

Fitness test	Rating % (n)			
	Very good	Good	Adequate	Poor
Arm bending	34.68 (60)	38.73 (67)	17.34 (30)	9.25 (16)
Slopes	55.49 (96)	38.73 (67)	4.05 (7)	1.73 (3)
Average	45.09 (78)	38.73 (67)	10.70 (19)	5.49 (10)

Table 5. Results of individual fitness tests according to sport status

Individual fitness tests	Professionalists (n= 39) Rating % (n)				Semi-professionalists (n= 134) Rating % (n)			
Fitness test	Very good	Good	Adequate	Poor	Very good	Good	Adequate	Poor
Arm bending	17.95 (7)	41.03 (16)	25.64 (10)	15.38 (6)	39.55 (53)	38.06 (51)	14.93 (20)	7.46 (10)
Slopes	20.51 (8)	58.97 (23)	12.82 (5)	7.69 (3)	65.67 (88)	32.84 (44)	1.49 (2)	0 (0)
Average	19.23 (8)	50.00 (20)	19.23 (13)	11.54 (5)	52.61 (71)	34.45 (48)	8.21 (11)	3.73 (5)

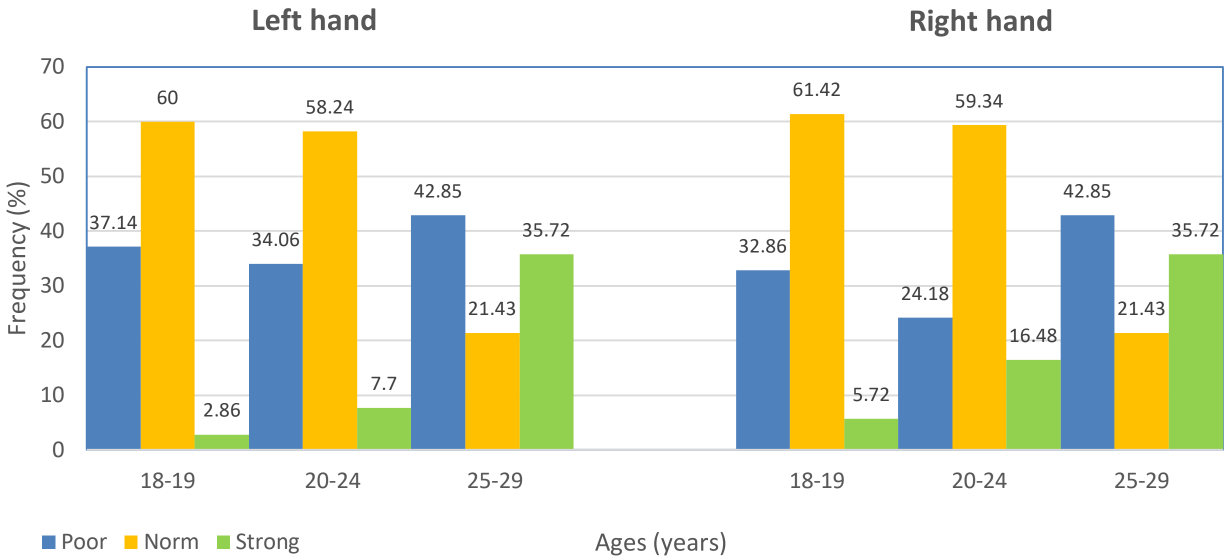

Figure 1. Comparison of grip strength in a group of esports players by age group

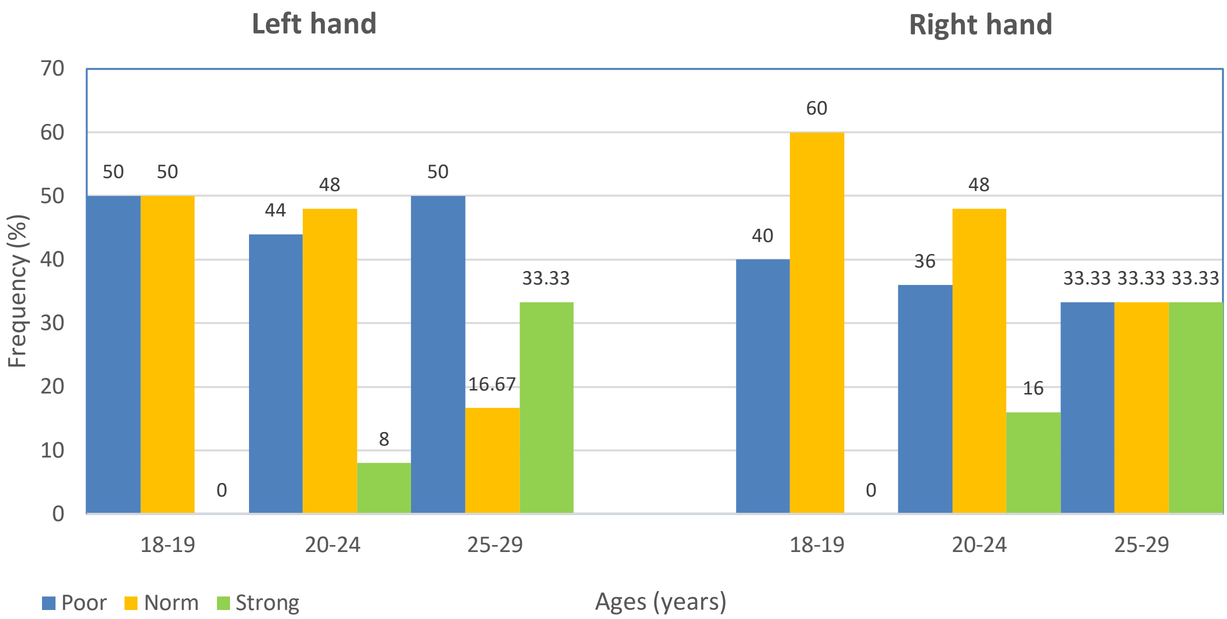

Figure 2. Comparison of grip strength in a group of professionals

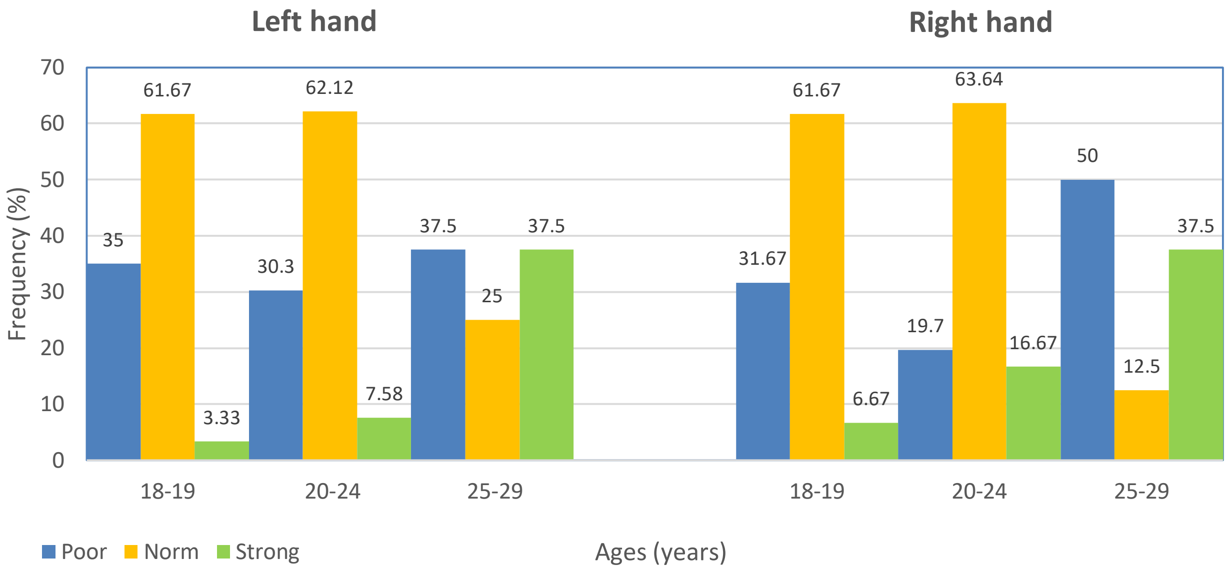

Figure 3. Comparison of grip strength in a group of semi-professionals

DISCUSSION

Previous studies have investigated PA levels among Spanish, German, Swedish, Chilean, Argentinean, Brazilian, Mexican, Arabic, Danish, Indonesian, Portuguese, American, and Malawian esports players [14-16,18,19,22,28,29]. The aim of the present study was to evaluate PA among Polish esport players. Most respondents reported moderate (37.9%) to low (36.4%) levels of PA, and no significant group differences in PA levels were found between professional and semi-professional esport players. These findings contrast with previous reports of professionals demonstrating moderate to high levels of PA with higher MET-min·week^{-1}, based on esports players from Europe, Latin America and Indonesia [15,16], Germany [9], and virtual footballers participating in the Portuguese Football Federation (FPF) [18,19].

One study also reported that 97% of collegiate esport players engaged in intensive PA [29]. Our study shows that Polish professionals were less physically active and spent significantly more time in a sedentary position than semi-professionals, due to more frequent and longer training sessions [8] and additional activities related to professional esport (e.g. meetings with a team, coach, participation in international tournaments). Trotter et al. 2020 found that players ranked in the top 10% had higher levels of PA compared to the remaining 90% of lower ranked players. In our study, professional esport players were significantly less active (1017 MET-min·week^{-1}) compared to the top 50 Indonesian MOBA players (3120.2 MET) [15] and professional esport players from Europe and Latin America (2429-2533 MET-min·week^{-1}) [16]. Others have shown that 80% of esports players did not meet WHO guidelines for PA [13], while 40% of college students did not engage in any form of physical activity [20].

Esports players, for example, may be at higher risk for health hazards and other common complaints (e.g., eye fatigue, musculoskeletal pain) than men of similar age [20]. It has been suggested that prolonged game playing may correlate with a higher BMI [30], but a strong association between game playing and the development of the obesity syndrome has not been conclusively established [31]. In the current study, male gamers were mostly of normal body weight (62.8%), which was a higher percentage than observed in German esports players (51%) [9]. A smaller proportion of Polish gamers were overweight (20.9%) and obese (7.7%). Similar results were reported by Giakoni-Ramírez et al. 2022, where 49.6% of the players had a normal body mass and 7.3% were obese. According to Trotter et al. 2020, esports players from the United States, Australia, Canada, Germany, and the United Kingdom were mostly of normal weight and obese.

Exercise capacity is largely determined by the proper functioning of the cardiovascular and respiratory systems. Determining the maximal physiological parameters of eSports players provides a quantitative assessment of the health status of the subjects. The VO_{2max} values of 41.92±5.41 mL·kg^{-1}·min^{-1} in the present study indicate an average level (according to the standards of the American College of Sports Medicine and the American Heart Association) of cardiorespiratory fitness in the study of esports players [32-34]. Similarly, according to the accepted norms for 20-29 year old Finnish men (as part of the FinFit-2017 study), the VO_{2max} values obtained here allow us to classify male esports players with an average level of cardiorespiratory fitness (range 41.64 to 41.98 mL·kg^{-1}·min^{-1}) [35]. It is worth noting that according to the somewhat more "rigorous" VO_{2max} classification developed by Irma Astrand in 1960 [36], esports players could be defined as men with an adequate (range 39 to 43 mL·kg^{-1}·min^{-1}) level of aerobic capacity. The reported average level of cardiorespiratory fitness is most likely due to the prevalence of moderate (38%) and low (36.4%) PA in our assessment of esports players.

Comparing the current recorded VO_{2max} with other findings in young men (using a bicycle ergometer), it can be seen that aerobic capacity tends to increase with higher levels of self-reported PA. Similar mean VO_{2max} values (44.2±2.8 mL·kg^{-1}·min^{-1}) were found by Marsh and Martin et al. 1997 and Claytor et al. 1988 (45.5±1.0 mL·kg^{-1}·min^{-1}) in young cohorts reporting low and moderate levels of PA [37,38]. In recreationally active students, VO_{2max} values averaged between 45 and 50 mL·kg^{-1}·min^{-1} [39-41]. VO_{2max} values of 45±8 mL·kg^{-1}·min^{-1} were recorded in the study by Hodgson et al. 2018, which included 25-year-old students who reported PA levels of approximately four recreational training sessions per week [41]. Higher VO_{2max} values have been reported in recreationally active students by Wilkerson et al. 2004 (50.0 ± 1.7 mL·kg^{-1}·min^{-1}) and Majerczak et al. 2006 (50.9 ± 5.2 mL·kg^{-1}·min^{-1}). An even higher level of aerobic capacity (VO_{2max} = 52.9±4.7 mL·kg^{-1}·min^{-1}) has been demonstrated in college athletes [42]. The highest VO_{2max} values (60 to more than 70 mL·kg^{-1}·min^{-1}) have been reported in young male endurance athletes (runners, cyclists and cross-country skiers) [38,43-46]. Conversely, very low VO_{2max} values (33.6±5.4 mL·kg^{-1}·min^{-1}) were found in a study of young people (women and men aged 18-28 years) with a sedentary lifestyle [47].

It should be noted that the mode of exercise can affect cardiorespiratory performance. In particular, during exercise tests performed on a cycle ergometer, subjects typically achieved lower VO_{2max} values (by a few to several percent) compared to running efforts performed on a mechanical treadmill [48,49]. This is due in part to greater local fatigue of the lower limb muscles during exercise on the cycle ergometer, resulting in premature termination of the exercise test, as well as greater activation of muscle mass during these running efforts [49,50]. In one such example, a group of non-training young men (21.6±1.4 years old) recorded VO_{2max} values of 54.5±3.6 mL·kg^{-1}·min^{-1} during a running test on a mechanical treadmill [51], which were more than 20% higher than those observed in the esports players in the present study. It is also worth noting that indirect methods of VO_{2max} assessment can yield similar results to those reported here. Bragada et al. 2022 used a step test (StepTest4all) to estimate a VO_{2max} volume of 47.75±6.71 mL·kg^{-1}·min^{-1} in nontraining young men [52], and Khammassi et al. 2018 estimated a VO_{2max} volume of 42.7±5.3 mL·kg^{-1}·min^{-1} in overweight and obese (BMI = 29.9±2.2 kg/m^2) 20-year-old men based on the results of a field running test (VAMEVAL test) [53].

The maximal VO_{2max} achieved in these studies (210.29±42.63 W) was lower than in exercise tests (including cycle ergometry) in healthy young men of similar age [39-41,54] and much lower than in peers training for running trials [43,45,55-56]. In studies of recreationally active men of similar age, maximal aerobic power was significantly higher than that recorded in the esports players in the present study. Wilkerson et al. 2004 reported PO at VO_{2max} of 356±8 W and Hodgson et al. 2018 333±55 W. Higher PO at VO_{2max} (293±29 W) was also reported by Majerczak et al. 2006 and Grandys et al. 2009 in students of the Academy of Physical Education (256±24 W). Much higher PO values at VO_{2max} were, as expected, recorded in endurance athletes. Lucia et al. 2001 conducted studies in professional road cyclists and recorded more than twice the maximum aerobic power of 517±11 W compared to our results, while Michalik et al. 2021 recorded 388±40 W in younger (16 to 18 year old) cyclists, slightly higher than Pallarés et al. 2020 (366±26 W) in their study in triathletes and cyclists.

In the current study, HR at AeT (146.20±6.94 beats·min^{-1}; 76.47±2.00 %HR_{max}) was lower than that of sprinters (159 beats·min^{-1}; 86.0 %HR_{max}) and distance runners (156 beats·min^{-1}; 86.6 %HR_{max}) of similar age (21 years) [57]. However, a comparison of the cardiovascular response to AeT in young (16-18 year old) cyclists, in whom HR was measured at an intensity corresponding to maximal fat oxidation (FAT_{max}), showed a lower AeT intensity (124±15 beats·min^{-1}; 63.5±7.7 %HR_{max}) than in esports players, but the power generated by the cyclists at this intensity was on average 14 W higher (104.4±52.8 W) [45].

Compared to physically active but not athletically trained 20-year-olds, the power generated by gamers at the AeT level (90.80±27.19 W) at a cadence of 60 rpm was significantly lower than the power achieved at the LT threshold level in studies by Majerczak et al. 2006 (160±36 W), Majerczak et al. 2017 (123±9 W) [58], and Grandys et al. 2009 (average 120 W). In the cited 2006 study, the HR at the LT threshold was slightly lower (140±13 beats·min^{-1}) than in the esports players in the present study (147±7 beats·min^{-1}), while the mean relative workload (74% HR_{max}) was similar to that of the esports players (76% HR_{max}) [40]. In this case, the lower value of power generated at the AeT level by esports players compared to physically active men, despite a comparable relative load (%HR_{max} at AeT), may indicate a lower mechanical efficiency of the lower limb muscles in this group. However, to further explain this phenomenon, studies with direct analysis of respiratory gas exchange are needed to compare the relationship between VO2 increase and power produced [59-61].

The power produced at AnT in the esports group (149.91±29.91 W) was lower than that reported in other studies of physically active young men. For example, Wilkerson et al. 2004 reported a critical power of 280±8 W and Thorland et al. 1994 [62] reported a power at onset of blood lactate accumulation (OBLA) of 211.4±46.5 W in 20-year-old men. Power values at the 4 mM OBLA threshold (161±4 W) in nontrained (VO_{2max} < 50 mL·kg^{-1}·min^{-1}) young men were similar to those reported by Messonnier et al. 2013, and HR at OBLA (158±5 beats·min^{-1}) and load (83±3 %HR_{max}) were lower than in the esports players in our study. The effect of training on power output is particularly evident in studies of cyclists, for whom exercise testing on a cycle ergometer has greater training specificity. One such study (in cyclists) reported similar HRs to esports players at VT2 (176±2 beats·min^{-1}; 91.7±0.9 %HR_{max}), but the power generated at VT2 (449.2±0.3 W) [43] was almost three times higher than that at AnT in esports players. Another study in a cycling cohort observed power values (at the OBLA level) of 259±10 W, and the cardiovascular response (HR 168±3 beats·min^{-1}; 89±1 %HR_{max}) was similar to that recorded in the current esport sample of men [63].

We found that most of the esport players had a very good (45.09%) and good (58.73%) physical fitness status. However, only 10.70% of players were in the fair category and 5.5% were in the poor category. The results of the present study showed that the grip strength of gamers in the 18-19 (60% and 61.42%) and 20-24 (58.24% and 59.34%) age groups was at a normal level compared to gamers in the 25-29 age group, who mostly had poor strength (42.85%) (Figure 1). The preliminary results of this study indicate that eSports players can potentially be considered fit, which is important scientific evidence. Currently, there is very limited research on the physical fitness of esport players. Therefore, the results of our sample may provide useful information for future research. In a related study on Palu City esport players, most were classified as having a sufficient category of physical fitness, but none reached a high level [64].

The physical demands of esport players are three times higher than those of office workers and depend on the type of esport games, different platforms, and performance levels [65]. Similar to traditional sports, exercise and increased physical fitness can help meet the physical demands of professional esports players and influence their success [66,67]. Exercise and physical fitness may also be essential for various aspects of gaming performance, including attention, memory, information processing, task-switching abilities [66], mood, stress and/or anxiety [68], and sleep [69,70]. It has been suggested that health-promoting behaviors, such as stretching and strengthening tendons, hand, arm, and shoulder muscles, may prevent injuries and even end a professional gamer's career [67].

Data from authors who have studied other groups are interesting. Tammelin et al. 2002 examined the effectiveness of young men in terms of grip strength and core muscle strength and showed that young men engaged in heavy physical work had higher grip strength and core muscle endurance than young men engaged in light work [71]. In turn, Osailan 2021 demonstrated that effective use of smartphones in a group of young men from Saudi Arabia resulted in stronger hand grip and pinch grip strength [72]. Our findings should be compared with research on academic adolescents. Studies in groups of medical and psychotherapy students have shown conflicting results indicating low PA levels. [73-75]. On the other hand, other analyses have pointed out that students with a higher PA had better results in the strength test and the long jump [76], and also showed a higher general fitness compared to those with a lower level [77]. A low level of physical fitness was also found in the group of drivers in one of the recent studies [78]. Some evidence suggests that eSports players pay little attention to improving their physical fitness, which we believe is due to a lack of understanding of how it affects different aspects of game performance [79].

This article presents the first comprehensive findings on the cognition of physical activity, exercise capacity and physical fitness assessment among Polish professional and semi-professional esport players. Our findings fit into a growing interest of esports considering the fact that the majority of the world's gamers are adolescents and young adults who compete in a physically and mentally demanding virtual environment associated with potential adverse health-related effects [80]. PA is an intrinsic and integral part of a healthy lifestyle, and its adequate levels influence physical fitness, which determines health status, mobility, and overall functioning [81-83]. For gamers, PA is significant and has a positive impact on capacity and performance [66,84]. For esports players, these benefits are supported by a balanced diet adapted to daily energy expenditure and the consumption of products that may affect health and brain function [85], especially psychobiotics [86]. To our knowledge, many studies have focused on profiling health and PA in esports, while physical fitness in esports players seems to be overlooked, so further research in this area is needed. More and more professional players and their trainers are becoming aware of the importance of maintaining an adequate level of physical fitness for esports, which helps to increase concentration during the game [87,88]. There is no doubt that people involved in professional esports should be physically fit.

Study limitations

The current study is not without its limitations. First, the sample size was small and the groups unbalanced, which may lead to biased results. Although the IPAQ questionnaire is recommended and widely used to assess PA, the number of activities reported by esports players may be overestimated/underestimated compared to an objective measurement (e.g. wearable sensor) and the data obtained may be less reliable. Second, not all possible fitness tests were performed, so it is questionable whether the results obtained fully characterize the broader fitness capacity of the studied population. Therefore, there is a clear need for further monitoring of physiological parameters related to physical health using direct methods. Nevertheless, the information gained from the current experiment may still have prescriptive value for training staff involved in the preparation of eSports players, i.e. doctors, nutritionists, physiotherapists or psychologists.

CONCLUSION

1. The results of this study suggest that Polish esport players achieved low and moderate levels of PA. Esports players were characterized by an average level of cardiorespiratory fitness, and the amount of muscle power generated at the level of AeT, AnT and VO_{2max} was lower than published evidence on physically active men.
2. The physical fitness of the players was judged to be satisfactory, but further research is needed to confirm this unequivocally.
3. As esport becomes more professional and a viable career option, players should be encouraged to engage in regular PA, which is likely to correlate with improvements in exercise capacity and physical fitness, which are critical for health and esport performance.

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