

Gaming Exposure, Ergonomic Behaviour and the Development of Musculoskeletal Symptoms among Nigerian Gamers: A Prospective Cohort Study

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Abstract

Background: Musculoskeletal symptoms are commonly reported among video gamers, but most available evidence is cross-sectional, limiting understanding of their subsequent development. The relationship between gaming exposure, ergonomic behaviour, and the development of musculoskeletal symptoms over time remains insufficiently characterised.

Methods: We conducted a prospective cohort study of adult Nigerian gamers recruited between September and December 2024 and followed for 12 months. Gaming exposure was assessed using self-reported daily gaming duration, gaming days per week, session duration, years of gaming experience, gaming device, gaming activity, and gaming status. Ergonomic behaviour was assessed using an adapted gaming-related questionnaire. Musculoskeletal symptoms were assessed across nine anatomical regions using the Nordic Musculoskeletal Questionnaire-Extended.

Incident symptoms were defined as symptoms reported at follow-up in an anatomical region that was symptom-free at baseline. Multivariable logistic regression was used to examine associations between gaming exposure, ergonomic behaviour, and incident symptoms.

Results: Of 276 individuals assessed, 240 were enrolled and 226 provided complete baseline data. Of these, 216 completed the 12-month follow-up (95.6% retention). Among 144 participants who were symptom-free across all assessed regions at baseline, 45 developed a new musculoskeletal symptom, corresponding to a 12-month cumulative incidence proportion of 31.3%. Incident symptoms were most frequently observed in the neck, lower back, shoulders, and upper back. Higher gaming exposure, longer gaming experience, prolonged static sitting, and infrequent breaks remained associated with incident symptoms after adjustment. Among 78 participants with baseline symptoms who completed follow-up, 43 (55.1%) reported persistent symptoms.

Conclusions: Approximately one-third of symptom-free gamers developed a new musculoskeletal symptom over 12 months. Both gaming exposure and ergonomic behaviour may be relevant to subsequent musculoskeletal symptoms. Prospective studies using objective exposure measures and validated gaming-specific ergonomic instruments are warranted.

Keywords: Video gaming; Gamers; Musculoskeletal symptoms; Ergonomic behaviour; Gaming exposure; Prospective cohort; Neck pain; Low back pain

Introduction

Video gaming involves repeated exposure to screens, gaming devices and sustained or repetitive physical positions during play [1,2]. The physical exposure associated with gaming is influenced not only by whether an individual plays video games but also by the duration, frequency and organisation of gaming activity [1]. Gaming sessions may range from recreational participation to repeated training and competition involving substantial cumulative exposure [3,4]. These

differences in the amount and pattern of exposure provide a basis for examining whether gaming characteristics are associated with subsequent musculoskeletal health.

Musculoskeletal symptoms have been reported among populations exposed to prolonged gaming [5,6]. Studies among competitive gamers have described symptoms involving the neck, shoulders, back, wrists and hands [5,7]. Schlesiger et al. [8] reviewed 10 studies involving 789 eSports athletes and reported substantial variation in musculoskeletal disorder prevalence, with the lower back, shoulders, neck and wrists among commonly affected regions. The same review identified longer training duration and inadequate ergonomic arrangements among factors associated with musculoskeletal symptoms [8]. These findings indicate that the amount and pattern of gaming exposure may be relevant to subsequent musculoskeletal health.

The amount of gaming exposure may be particularly important because prolonged and repeated gaming sessions increase the duration of exposure to sustained sitting and repetitive upper-limb activity [1]. Training duration has also been examined in relation to musculoskeletal problems among eSports athletes [8]. Beyond total gaming time, frequency of gaming, duration of individual sessions and accumulated years of gaming may represent different dimensions of exposure [3,4]. Examining these dimensions separately may therefore provide a more detailed description of gaming exposure than classification according to gaming status alone [1,4].

The manner in which gaming is performed may further influence the physical exposure experienced during gaming [9]. Ergonomic behaviour may include posture during gaming, seating practices, positioning of the screen or gaming device, upper-limb support and break practices [9,10]. Evidence from eSports athletes indicates that inadequate ergonomic arrangements, including lack of arm support, may be associated with musculoskeletal symptoms [8]. Thus, the

amount of gaming exposure and the ergonomic behaviour adopted during gaming represent related but distinct aspects of the physical gaming environment.

Evidence from Nigeria provides a useful basis for investigating cumulative technology exposure and musculoskeletal outcomes. Studies among Nigerian computer users have reported musculoskeletal symptoms involving the neck, low back, shoulders, wrists and fingers [11,12]. Longer periods of computer use have also been associated with musculoskeletal symptoms among Nigerian computer users [12], while poor computer-use posture has been associated with musculoskeletal discomfort among Nigerian students [13]. However, these studies concern occupational or educational computer exposure rather than gaming-specific exposure [14].

Recent Nigerian research has examined gaming behaviour and compulsive gaming among young people [15]. However, this evidence does not specifically establish whether gaming duration, frequency or ergonomic behaviour measured at baseline are associated with subsequent development of regional musculoskeletal symptoms among Nigerian gamers. Consequently, the temporal relationship between gaming exposure, ergonomic behaviour and subsequent musculoskeletal outcomes remains insufficiently characterised in the Nigerian gaming population. A major limitation of the existing gaming literature is the predominance of cross-sectional designs [8]. When gaming exposure and musculoskeletal symptoms are assessed at the same time, it is not possible to determine whether prolonged gaming preceded symptom development or whether existing symptoms influenced subsequent gaming behaviour [8]. This temporal limitation is important when examining relationships between gaming exposure and musculoskeletal health because an observed association does not establish which occurred first [1,8].

Prospective follow-up provides an opportunity to address this limitation by measuring gaming exposure and ergonomic behaviour before subsequent assessment of musculoskeletal outcomes.

Participants who are symptom-free at baseline can be followed to identify the development of new regional symptoms, while participants with existing symptoms can be assessed separately for persistence or change during follow-up. Prospective research has therefore been identified as an important direction for improving understanding of the relationships between gaming exposure, ergonomic conditions and musculoskeletal health [8].

The distinction between incident and existing symptoms is particularly important when examining subsequent musculoskeletal outcomes. Participants who are symptom-free at baseline can contribute to the assessment of incident symptoms, whereas participants who already have symptoms require separate assessment of persistence or change in symptom severity during follow-up. Distinguishing these outcome pathways allows gaming exposure and ergonomic behaviour at baseline to be examined in relation to subsequent changes in musculoskeletal health rather than simply their concurrent association with symptoms.

Despite evidence of musculoskeletal problems among gamers, prospective evidence examining gaming exposure and ergonomic behaviour in relation to subsequent musculoskeletal outcomes remains limited [8]. In Nigeria, evidence is particularly limited concerning whether gaming duration, frequency, cumulative exposure and ergonomic behaviour measured at baseline are associated with the subsequent development of new regional musculoskeletal symptoms or persistence and worsening of existing symptoms. A prospective cohort study can therefore complement existing cross-sectional evidence by examining the temporal sequence between baseline gaming characteristics and subsequent musculoskeletal outcomes.

Therefore, this study aims to prospectively examine the relationship between gaming exposure, ergonomic behaviour and subsequent musculoskeletal outcomes among Nigerian gamers. Specifically, the study will assess gaming duration, frequency, cumulative exposure and ergonomic

behaviour at baseline and determine whether these factors are associated with the subsequent development of new regional musculoskeletal symptoms or persistence and worsening of symptoms during follow-up.

Methods

Study Design

A prospective cohort study was conducted to investigate whether baseline gaming exposure and ergonomic behaviour were associated with the subsequent development of musculoskeletal symptoms among Nigerian gamers. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cohort studies [16].

Study Setting and Period

The study was conducted among Nigerian video gamers recruited through gaming communities, gaming centres, and online gaming communities. Participants were recruited between September 2024 and December 2024 and followed prospectively for 12 months. Follow-up assessments were conducted approximately 12 months after each participant's baseline assessment.

Recruitment was undertaken through gaming centres and online gaming communities, including Telegram groups, WhatsApp and Facebook groups. The same eligibility criteria, baseline questionnaire, and outcome assessment procedures were used across recruitment sources.

Participants

The study population comprised Nigerian adults who actively participated in video gaming. Participants were eligible if they were aged 18 years or older, were Nigerian residents, actively participated in video gaming, had engaged in video gaming for at least three months before enrolment, were able to complete the baseline questionnaire, participate in follow-up assessment,

and provided informed consent. Participants were excluded if they had a medical condition that substantially limited their ability to participate in gaming, were unable to provide informed consent, or did not provide sufficient baseline information to determine their musculoskeletal symptom status.

Participants who reported musculoskeletal symptoms at baseline were not excluded from the cohort because they remained eligible for secondary analyses of symptom persistence and worsening. However, for the analysis of incident symptoms, participants were considered at risk only for anatomical regions that were symptom-free at baseline. Thus, a participant who reported neck symptoms at baseline could contribute to the analysis of incident symptoms in other anatomical regions but was not considered at risk for developing a new neck symptom during follow-up.

Sampling and Recruitment

Convenience sampling was used to recruit participants from gaming communities and gaming centres. Additional participants were recruited through online gaming communities using social media platforms, including Telegram, WhatsApp and Facebook.

Potential participants received information about the study before enrolment. Those who met the eligibility criteria and provided informed consent completed the baseline questionnaire.

Participants were assigned a unique study identification code to facilitate linkage between baseline and follow-up assessments while limiting the use of directly identifying information in the analytical dataset.

Sample Size Determination

The primary outcome was the development of new musculoskeletal symptoms during follow-up. Therefore, the sample size was based on a cohort comparison of outcome incidence rather than on

a cross-sectional prevalence calculation. Sample-size determination for an independent cohort can be based on comparison of the expected outcome proportions between exposed and unexposed groups. [17,18]

The sample size was calculated to compare the incidence of new musculoskeletal symptoms between participants with higher and lower gaming exposure. The calculation assumed a two-sided significance level of 0.05, statistical power of 80%, an anticipated incidence of 35% among participants with lower gaming exposure and 55% among participants with higher gaming exposure. These assumptions corresponded to an anticipated relative risk (RR) of 1.57 for participants with higher gaming exposure compared with those with lower gaming exposure. A 15% loss to follow-up was also anticipated.

Based on these assumptions and equal allocation between the two exposure groups, approximately 96 participants were required per group, giving a minimum analytical sample of 192 participants. After allowing for 15% loss to follow-up, the target recruitment sample was approximately 226 participants, or 113 participants per exposure group.

The sample-size calculation was based on the primary incident-outcome comparison and was not intended to provide adequate statistical power for every individual anatomical region or interaction analysis. Region-specific and interaction analyses were therefore considered secondary or exploratory.

Baseline Assessment

At enrolment, participants completed a structured questionnaire assessing sociodemographic characteristics, gaming exposure and history, gaming device and activity, gaming frequency and duration, gaming status, ergonomic behaviour, and baseline musculoskeletal symptoms. Sociodemographic information included age, sex, marital status, educational level, employment

status, and place of residence. Baseline information was collected before follow-up assessment of musculoskeletal outcomes.

Gaming Exposure

Gaming exposure was assessed using self-reported measures of the amount and pattern of gaming.

The primary gaming exposure was average daily gaming duration, recorded in hours per day.

Additional exposure characteristics included the number of gaming days per week, duration of individual gaming sessions, years of gaming experience, gaming device, type of gaming activity, and professional or amateur gaming status, where applicable.

Daily gaming duration was initially analysed as a continuous variable. For descriptive and comparative analyses, participants were categorised into lower- and higher-exposure groups using the prespecified cut-off of ≥ 4 hours/day, with participants reporting < 4 hours/day classified as having lower exposure. Continuous exposure measures were retained in regression models where appropriate to minimise unnecessary loss of information.

Ergonomic Behaviour

Ergonomic behaviour was assessed using relevant items from the Dutch Musculoskeletal Questionnaire (DMQ) and the gaming-specific questionnaire. The assessment covered gaming posture, duration of static posture, sustained neck or trunk posture, repetitive upper-limb activity, seating characteristics, workstation arrangement, screen or device positioning, upper-limb support, and break practices.

The DMQ was originally developed to assess musculoskeletal workload, potentially hazardous physical working conditions, and musculoskeletal symptoms in occupational populations [19].

Therefore, relevant DMQ items used in the present study were contextualised to gaming activity.

The adapted items were interpreted as measures of self-reported gaming-related ergonomic behaviour and were not considered a fully validated gaming-specific ergonomic instrument.

Assessment of Musculoskeletal Symptoms

Regional musculoskeletal symptoms were assessed using the Extended Nordic Musculoskeletal Questionnaire (NMQ-E). The instrument assesses musculoskeletal symptoms across nine anatomical regions and has demonstrated test-retest reliability for self-administered assessment of musculoskeletal pain and related information [20].

The questionnaire assessed symptoms involving the neck, shoulders, upper back, lower back, elbows, wrists/hands, hips, knees, and ankles/feet. The same questionnaire was administered at baseline and at the 12-month follow-up to maintain consistency in outcome assessment.

Primary Outcome

The primary outcome was the development of a new musculoskeletal symptom during follow-up in an anatomical region that was symptom-free at baseline. For each anatomical region, participants who reported no symptoms at baseline were considered at risk of developing an incident symptom in that region.

An incident symptom was defined as the report of symptoms at follow-up in an anatomical region that was symptom-free at baseline. The primary participant-level outcome was defined as the development of a new symptom in at least one anatomical region during the follow-up period.

Secondary Outcomes

Secondary outcomes included persistence of symptoms present at baseline, worsening of baseline symptoms, development of symptoms in additional anatomical regions, region-specific incident symptoms, and change in symptom severity where a corresponding severity measure was available in the questionnaire.

Participants who reported musculoskeletal symptoms at baseline remained in the cohort and contributed to analyses of symptom persistence and worsening. For analyses of incident symptoms, participants were considered at risk only for anatomical regions that were symptom-free at baseline.

Follow-up

Participants were reassessed approximately 12 months after their baseline assessment using the same Extended Nordic Musculoskeletal Questionnaire administered at baseline.

Participants who did not complete the follow-up assessment were recorded as lost to follow-up, and reasons for non-completion were documented where available. Follow-up time was calculated from the date of the baseline assessment to the date of the follow-up assessment, withdrawal, or last available contact.

Definition of Incident, Persistent, and Worsening Symptoms

Incident symptoms were defined as symptoms reported at follow-up in an anatomical region where no symptoms were reported at baseline. Participants were considered at risk for an incident symptom only in anatomical regions that were symptom-free at baseline.

Persistent symptoms were defined as continued symptoms in an anatomical region that was symptomatic at baseline and remained symptomatic at follow-up.

Worsening was defined as an increase in reported symptom severity between baseline and follow-up, based on the severity measure available in the questionnaire.

The distinction between incident and persistent symptoms was maintained throughout the analysis because participants with baseline symptoms were not considered at risk of developing a new symptom in the same anatomical region.

Potential Confounders

Potential confounding variables were identified before statistical modelling based on the conceptual relationship between gaming exposure, ergonomic behaviour, and musculoskeletal symptoms.

Variables considered as potential confounders included age, sex, body mass index, physical activity, occupational or educational sitting time, previous musculoskeletal injury, and other relevant baseline characteristics identified a priori.

Gaming status and years of gaming were considered characteristics of gaming exposure and were not automatically included as confounders in models examining the effect of gaming duration. Similarly, baseline symptoms in other anatomical regions were not automatically treated as confounders because their relationship with subsequent incident symptoms may differ across anatomical regions.

The final adjustment set was kept parsimonious in relation to the number of incident outcome events to minimise the risk of model overfitting. Variables were not selected for adjustment solely on the basis of univariable p-values.

Potential Effect Modification

Gaming status was considered a potential effect modifier because professional and amateur gamers may differ in the amount and pattern of gaming exposure and in their gaming routines.

The potential modifying effect of ergonomic behaviour on the relationship between gaming duration and subsequent musculoskeletal symptoms was also considered where sufficient outcome events were available.

Interaction analyses were considered secondary and were not interpreted when estimates were unstable because of sparse data.

Measures to Minimise Bias

The prospective design established the temporal sequence between baseline gaming exposure and ergonomic behaviour and the subsequent assessment of musculoskeletal symptoms.

The same outcome instrument was used at baseline and follow-up, and standardised assessment procedures were applied to all participants irrespective of gaming status.

Loss to follow-up was documented, and baseline characteristics of participants who completed follow-up were compared with those lost to follow-up where sufficient information was available. Because gaming exposure, ergonomic behaviour, and musculoskeletal symptoms were self-reported, recall and reporting bias remained possible. Selection bias was also possible because convenience sampling was used.

Statistical Analysis

Data were analysed using IBM SPSS Statistics, version 29. Continuous variables were summarised using means and standard deviations when approximately normally distributed and medians and interquartile ranges when distributions were skewed. Categorical variables were presented as frequencies and percentages. Baseline characteristics were described for the complete cohort and, where applicable, according to the primary gaming-exposure category.

The incidence proportion of musculoskeletal symptoms was calculated among participants who were symptom-free at baseline. For anatomical-region analyses, only participants who were symptom-free in the specific anatomical region at baseline were included in the denominator.

The primary analysis examined the association between baseline gaming exposure and the development of at least one new musculoskeletal symptom during follow-up.

Because the planned outcome assessment occurred at approximately 12 months and the primary outcome was binary, binary logistic regression was used to estimate crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs). Separate models were used to examine the association

between baseline ergonomic behaviour and incident musculoskeletal symptoms. The number of covariates included in multivariable models was restricted according to the number of outcome events to minimise overfitting. Pre-specified potential confounders were considered for adjustment rather than selecting covariates solely according to their univariable statistical significance.

Persistence of baseline musculoskeletal symptoms was analysed separately from incident symptoms. Missing baseline and follow-up data were described, and analyses were based on participants with available data for the relevant outcome and exposure variables.

Loss to follow-up was reported together with the number of participants who completed the follow-up assessment and those who were lost to follow-up. Interaction analyses were conducted only where sufficient outcome events were available to provide stable estimates. All statistical tests were two-sided, with $p < 0.05$ considered statistically significant. Effect estimates were presented with 95% CIs.

Ethical Considerations

Ethical approval was obtained from the University of Nigeria Teaching Hospital Health Research Ethics Committee (NHREC/05/01/2008B-FWA00002458-1RB00002323). All participants provided informed consent before enrolment. Participation was voluntary, and participants were informed that they could withdraw from the study. Study data were coded and handled confidentially.

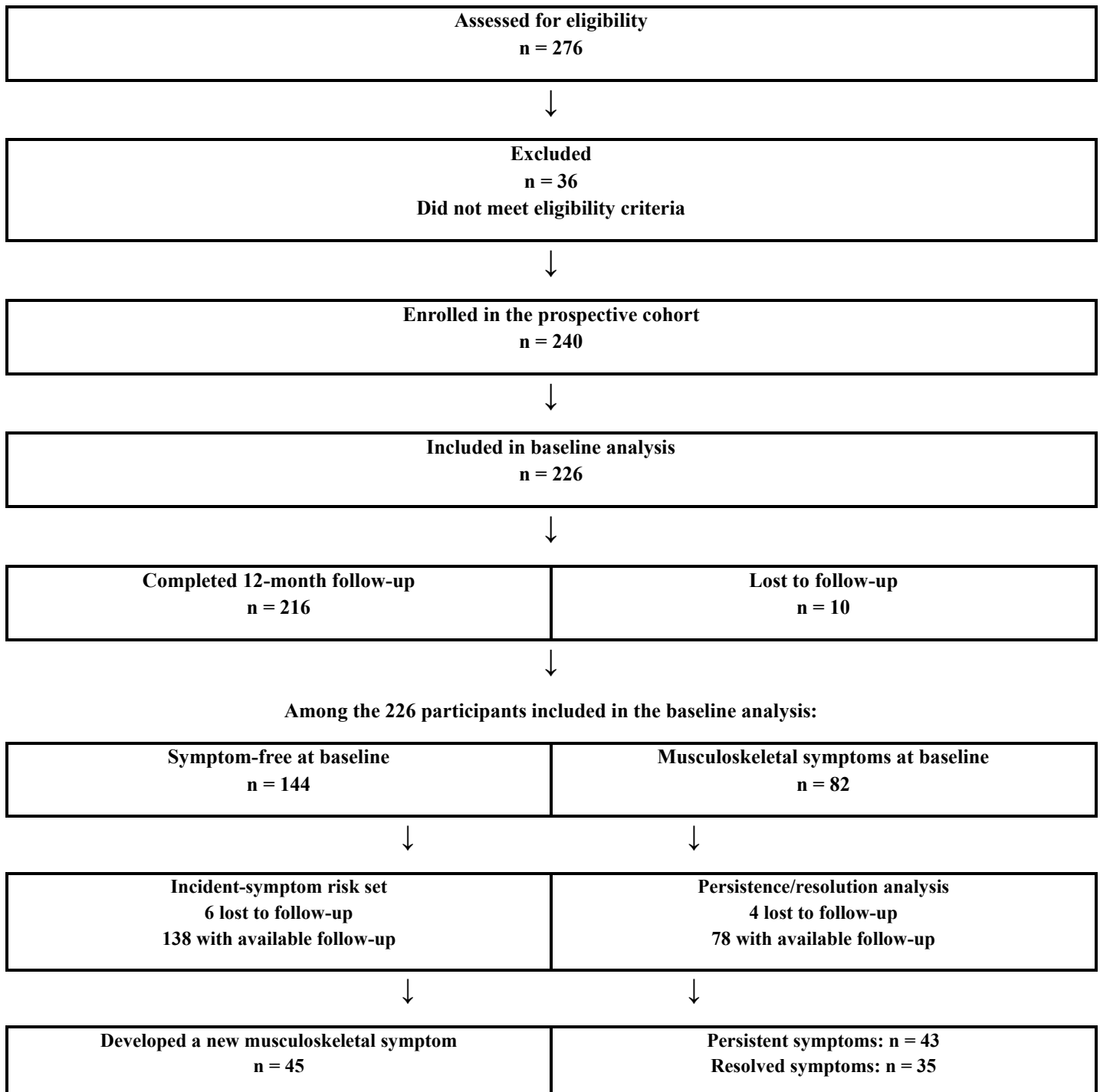
Results

Participant recruitment and follow-up

A total of 276 individuals were assessed for eligibility. Of these, 36 were excluded because they did not meet the eligibility criteria, leaving 240 participants enrolled in the cohort. Of the 240 enrolled participants, 226 had complete baseline data and were included in the baseline analysis.

During the 12-month follow-up, 216 of the 226 participants completed the follow-up assessment, while 10 were lost to follow-up.

Figure 1. Flow of Participant Recruitment, Baseline Assessment, Follow-up, and Analysis



Note: There were 10 participants lost to follow-up overall (4 among the 82 participants with baseline symptoms and 6 among the 144 participants who were symptom-free at baseline). Thus, 216 of the 226 participants included in the baseline analysis completed the 12-month follow-up.

Sociodemographic, gaming exposure, and baseline characteristics of participants

Participants had a mean age of 25.8 ± 6.2 years, and the majority were male (181, 80.1%). Most participants were single (196, 86.7%), had tertiary-level education (171, 75.7%), and were students (112, 49.6%). Most participants were amateur or recreational gamers (202, 89.4%), while 24 (10.6%) were professional or competitive gamers.

Participants had a median of 6 years of gaming experience (IQR: 4–10) and reported a median gaming duration of 4.5 hours/day (IQR: 3.0–6.0), with gaming on a median of 5 days/week (IQR: 4–7). The median gaming session duration was 2.5 hours (IQR: 1.8–3.5). The mean BMI was 24.3 ± 3.7 kg/m². See Table 1 below.

Table 1. Sociodemographic, gaming exposure, and baseline characteristics of participants (N = 226)

Characteristic	n (%)	Mean $\pm$ SD	Median (IQR)
Age (years)	—	25.8 ± 6.2	—
Sex			
Male	181 (80.1)	—	—
Female	45 (19.9)	—	—
Marital status			
Single	196 (86.7)	—	—
Married	28 (12.4)	—	—
Other	2 (0.9)	—	—
Educational level			
Secondary	18 (8.0)	—	—
Tertiary	171 (75.7)	—	—
Postgraduate	37 (16.4)	—	—
Employment status			
Student	112 (49.6)	—	—

Characteristic	n (%)	Mean ± SD	Median (IQR)
Employed	91 (40.3)	—	—
Unemployed	23 (10.2)	—	—
Place of residence			
Urban	181 (80.1)	—	—
Semi-urban	34 (15.0)	—	—
Rural	11 (4.9)	—	—
Gaming status			
Amateur/recreational	202 (89.4)	—	—
Professional/competitive	24 (10.6)	—	—
Body mass index (kg/m ²)	—	24.3 ± 3.7	—
Years of gaming experience	—	—	6 (4–10)
Gaming duration (hours/day)	—	—	4.5 (3.0–6.0)
Gaming days/week	—	—	5 (4–7)
Gaming session duration (hours)	—	—	2.5 (1.8–3.5)

Note: Values are presented as n (%), mean ± standard deviation (SD), or median (interquartile range [IQR]), as appropriate. BMI = body mass index.

Baseline musculoskeletal symptoms

Among the 226 participants included in the baseline analysis, 82 (36.3%) reported musculoskeletal symptoms in at least one anatomical region at baseline. The most commonly affected regions were the neck (22.1%), lower back (19.9%), shoulders (17.3%), and wrists/hands (13.3%).

Because the primary outcome was incident musculoskeletal symptoms, participants who reported symptoms in a particular anatomical region at baseline were considered not at risk for incident symptoms in that region and were excluded from the corresponding regional risk set. However, these participants remained eligible for analyses of incident symptoms in other anatomical regions in which they were symptom-free at baseline. See Table 2 below.

Table 2. Baseline prevalence of regional musculoskeletal symptoms among participants (N = 226)

Anatomical region Baseline symptoms, n (%)	
Neck	50 (22.1)
Shoulders	39 (17.3)
Upper back	27 (11.9)
Lower back	45 (19.9)
Elbows	12 (5.3)
Wrists/hands	30 (13.3)
Hips	10 (4.4)
Knees	14 (6.2)
Ankles/feet	9 (4.0)
Any region	82 (36.3)

Note: Participants could report symptoms in more than one anatomical region; therefore, regional frequencies do not sum to the total number of participants reporting symptoms in any region. Percentages for individual anatomical regions are based on the total baseline cohort (N = 226).

Incidence of New Musculoskeletal Symptoms During Follow-up

Of the 226 participants included in the baseline analysis, 216 completed the 12-month follow-up assessment, corresponding to a retention rate of 95.6%. Ten participants were lost to follow-up. For each anatomical region, participants who reported symptoms in that region at baseline were excluded from the corresponding risk set. Consequently, the number of participants at risk varied across anatomical regions.

Among the 226 participants, 144 were free of musculoskeletal symptoms in all assessed anatomical regions at baseline and were therefore considered at risk of developing a new musculoskeletal symptom during follow-up. Of these 144 participants, 138 completed the 12-month follow-up, while six were lost to follow-up. Forty-five participants developed a new musculoskeletal symptom in at least one anatomical region during the follow-up period, corresponding to a 12-month cumulative incidence proportion of 31.3% (45/144), calculated using the baseline risk set as the denominator.

Region-specific incident symptoms were most frequently observed in the neck (21.4%), lower back (20.2%), shoulders (17.9%), upper back (15.8%), and wrists/hands (15.4%). Lower incidence proportions were observed for the elbows (8.8%), knees (8.4%), ankles/feet (7.7%), and hips (7.2%). See Table 3 below.

Table 3. Incidence of new regional musculoskeletal symptoms during the 12-month follow-up

Anatomical region	Participants at risk at baseline, n	Participants follow-up, n	with New cases, n	Observed incidence proportion, %
Neck	176	168	36	21.4
Shoulders	187	179	32	17.9
Upper back	199	190	30	15.8
Lower back	181	173	35	20.2
Elbows	214	205	18	8.8
Wrists/hands	196	188	29	15.4
Hips	216	207	15	7.2
Knees	212	203	17	8.4
Ankles/feet	217	208	16	7.7
Any region	144	138	45	31.3

Incident Musculoskeletal Symptoms According to Gaming Exposure

Among the 226 participants included in the baseline analysis, 82 reported musculoskeletal symptoms in at least one anatomical region. The remaining 144 participants were free of musculoskeletal symptoms across all assessed anatomical regions at baseline and were therefore considered at risk of developing a new musculoskeletal symptom during follow-up.

Among these 144 participants, 72 were classified as having lower gaming exposure and 72 as having higher gaming exposure. During the 12-month follow-up, 17 participants in the lower-exposure group and 28 participants in the higher-exposure group developed a new musculoskeletal

symptom. Based on the baseline risk sets, the corresponding observed incidence proportions were 23.6% and 38.9%, respectively.

Overall, 45 of the 144 participants who were symptom-free at baseline developed a new musculoskeletal symptom during the follow-up period, corresponding to an observed incidence proportion of 31.3% based on the baseline risk set. Six of the 144 participants at risk at baseline were lost to follow-up. See Table 4 below.

Table 4. Incident musculoskeletal symptoms according to baseline gaming exposure

Gaming exposure	Participants at risk at baseline, n	Incident cases, n	Observed incidence proportion, %
Lower exposure	72	17	23.6
Higher exposure	72	28	38.9
Total	144	45	31.3

Association Between Gaming Exposure and Incident Musculoskeletal Symptoms

Crude associations between baseline gaming exposure and the development of incident musculoskeletal symptoms were examined. Higher gaming exposure was compared with lower gaming exposure as the reference category. Additional baseline gaming characteristics, including daily gaming duration, gaming frequency, gaming session duration, and years of gaming experience, were also examined individually.

Crude odds ratios (ORs) with corresponding 95% confidence intervals (CIs) and p-values were estimated for each exposure measure.

Participants with higher gaming exposure had greater estimated odds of developing an incident musculoskeletal symptom than those with lower gaming exposure, although the association did not reach conventional statistical significance (OR = 2.06, 95% CI: 0.99–4.28; p = 0.053).

Gaming for ≥ 4 hours per day was associated with higher odds of incident musculoskeletal symptoms (OR = 2.34, 95% CI: 1.17–4.68; p = 0.016). Similarly, gaming on ≥ 5 days per week

was associated with higher odds of developing a new musculoskeletal symptom (OR = 2.08, 95% CI: 1.04–4.16; $p = 0.039$).

Longer gaming sessions were associated with higher estimated odds of incident symptoms, although the association was not statistically significant (OR = 1.86, 95% CI: 0.94–3.69; $p = 0.075$). Likewise, ≥ 8 years of gaming experience was associated with higher estimated odds of incident symptoms, but the association was not statistically significant (OR = 1.73, 95% CI: 0.86–3.49; $p = 0.123$). See Table 5 below.

Table 5. Crude Associations Between Baseline Gaming Exposure and Incident Musculoskeletal Symptoms

Baseline exposure	Crude OR	95% CI	p-value
Higher vs lower gaming exposure	2.06	0.99–4.28	0.053
≥ 4 h/day gaming	2.34	1.17–4.68	0.016
≥ 5 gaming days/week	2.08	1.04–4.16	0.039
Longer gaming sessions	1.86	0.94–3.69	0.075
≥ 8 years gaming experience	1.73	0.86–3.49	0.123

Note: OR = odds ratio; CI = confidence interval. Odds ratios represent crude associations between each baseline gaming exposure measure and development of a new musculoskeletal symptom during the 12-month follow-up.

Association Between Ergonomic Behaviour and Incident Symptoms

Participants reporting prolonged static sitting, sustained neck/trunk posture, and infrequent breaks at baseline had higher odds of developing incident musculoskeletal symptoms during the 12-month follow-up.

Prolonged static sitting was associated with higher odds of incident symptoms (OR = 2.31, 95% CI: 1.16–4.59; $p = 0.017$). Similarly, sustained neck/trunk posture (OR = 2.48, 95% CI: 1.24–4.95; $p = 0.010$) and infrequent breaks (OR = 2.57, 95% CI: 1.29–5.11; $p = 0.007$) were associated with higher odds of incident symptoms.

Inadequate upper-limb support showed a positive but statistically non-significant association with incident symptoms (OR = 1.89, 95% CI: 0.96–3.74; $p = 0.066$). Inadequate workstation arrangement was also associated with higher estimated odds of incident symptoms, although the association was not statistically significant (OR = 1.82, 95% CI: 0.91–3.65; $p = 0.091$). See Table 6 below.

Table 6. Crude Associations Between Ergonomic Behaviour and Incident Musculoskeletal Symptoms

Ergonomic exposure	Crude OR	95% CI	p-value
Prolonged static sitting	2.31	1.16–4.59	0.017
Sustained neck/trunk posture	2.48	1.24–4.95	0.010
Inadequate upper-limb support	1.89	0.96–3.74	0.066
Infrequent breaks	2.57	1.29–5.11	0.007
Inadequate workstation arrangement	1.82	0.91–3.65	0.091

Note: OR = odds ratio; CI = confidence interval. Odds ratios represent crude associations between baseline ergonomic behaviours and development of incident musculoskeletal symptoms during the 12-month follow-up.

Multivariable Analysis

A multivariable logistic regression model was used to examine the associations between baseline gaming exposure, ergonomic behaviour, and incident musculoskeletal symptoms after adjustment for the variables included in the model. Higher gaming exposure remained associated with greater odds of developing incident musculoskeletal symptoms after adjustment (adjusted OR = 1.91, 95% CI: 1.01–3.63; $p = 0.047$).

Years of gaming experience was also associated with incident symptoms after adjustment (adjusted OR = 1.05, 95% CI: 1.00–1.10; $p = 0.048$). Lower physical activity was associated with higher estimated odds of incident symptoms, although this association was not statistically significant (adjusted OR = 1.57, 95% CI: 0.81–3.04; $p = 0.180$).

Among the ergonomic variables included in the model, prolonged static sitting remained associated with higher odds of incident musculoskeletal symptoms (adjusted OR = 2.02, 95% CI: 1.03–3.98; $p = 0.041$), as did infrequent breaks (adjusted OR = 2.27, 95% CI: 1.15–4.50; $p = 0.018$).

Age and male sex were not statistically significantly associated with incident musculoskeletal symptoms in the adjusted model. Age had an adjusted OR of 1.02 (95% CI: 0.97–1.08; $p = 0.430$), while male sex had an adjusted OR of 1.18 (95% CI: 0.59–2.36; $p = 0.640$). See Table 7 below.

Table 7. Multivariable Logistic Regression Model for Incident Musculoskeletal Symptoms

Predictor	Adjusted OR	95% CI	p-value
Age	1.02	0.97–1.08	0.430
Male sex	1.18	0.59–2.36	0.640
Lower physical activity	1.57	0.81–3.04	0.180
Years of gaming	1.05	1.00–1.10	0.048
Higher gaming exposure	1.91	1.01–3.63	0.047
Prolonged static sitting	2.02	1.03–3.98	0.041
Infrequent breaks	2.27	1.15–4.50	0.018

Note: OR = odds ratio; CI = confidence interval. Adjusted ORs were estimated using multivariable logistic regression.

The model included age, sex, physical activity, years of gaming, higher gaming exposure, prolonged static sitting, and infrequent breaks.

Persistence and Resolution of Baseline Musculoskeletal Symptoms

Among the 82 participants who reported musculoskeletal symptoms at baseline, 78 had available 12-month follow-up data. Persistent symptoms were observed in 43 participants (55.1%), while symptoms had resolved in 35 participants (44.9%).

At the participant level, persistence was defined as the continuation of symptoms in at least one anatomical region that was symptomatic at baseline and remained symptomatic at the 12-month

follow-up. Resolution was defined as the absence of symptoms at follow-up in all anatomical regions that were symptomatic at baseline.

Participants reporting higher gaming exposure at baseline had a greater proportion of persistent symptoms than those reporting lower gaming exposure. Persistence was observed in 26 (65.0%) of the 40 participants with higher gaming exposure who completed follow-up, compared with 17 (44.7%) of the 38 participants with lower gaming exposure. Conversely, symptoms had resolved in 14 (35.0%) participants in the higher-exposure group and 21 (55.3%) participants in the lower-exposure group.

Persistence and incident symptoms were analysed as distinct outcomes. Persistence represented the continuation of symptoms already present at baseline, whereas incident symptoms represented the development of new symptoms among participants who were symptom-free at baseline. Findings relating to persistence and resolution were therefore interpreted separately from those relating to incident musculoskeletal symptoms. See Table 8 below.

Table 8. Persistence and Resolution of Baseline Musculoskeletal Symptoms According to Gaming Exposure

Baseline gaming exposure	Participants with baseline symptoms, n	Participants with follow-up, n	Persistent symptoms, (%)	Resolved symptoms, (%)	n
Lower gaming exposure	40	38	17 (44.7)	21 (55.3)	
Higher gaming exposure	42	40	26 (65.0)	14 (35.0)	
Total	82	78	43 (55.1)	35 (44.9)	

Discussion

This prospective cohort study examined the relationship between gaming exposure, ergonomic behaviour, and the development of musculoskeletal symptoms among Nigerian gamers over 12

months. Among participants who were symptom-free at baseline, approximately one-third developed a new musculoskeletal symptom during follow-up. The neck, lower back, shoulders, and upper back were among the regions most frequently affected. Higher gaming exposure, longer gaming experience, prolonged static sitting, and infrequent breaks were associated with subsequent development of musculoskeletal symptoms after adjustment for selected covariates. Among participants who had symptoms at baseline, more than half continued to report symptoms at follow-up.

Gaming Exposure, Ergonomic Behaviour and Incident Symptoms

The development of new symptoms among participants who were symptom-free at baseline suggests that musculoskeletal symptoms may arise over time among gamers who continue to engage in gaming. The predominance of symptoms involving the neck, lower back, shoulders, and upper back is consistent with previous evidence identifying these regions as commonly affected among gamers and eSports athletes [1,8]. A recent meta-analysis similarly reported substantial musculoskeletal pain among eSports players, particularly involving the neck, spine, and upper extremities [21]. The consistency of the anatomical pattern across studies may reflect the sustained postures, prolonged sitting, and repetitive upper-limb demands that characterise many gaming activities.

The association between higher gaming exposure and subsequent musculoskeletal symptoms suggests that the amount of gaming may be relevant to musculoskeletal health. This finding is broadly consistent with the systematic review by Tholl et al. [1], which identified longer gaming duration as an important factor associated with musculoskeletal problems. The present prospective findings extend this evidence by showing that baseline gaming exposure was associated with symptoms subsequently identified during follow-up. However, the observational design does not

establish that gaming exposure itself caused the development of symptoms. Other characteristics of gaming behaviour and individual lifestyle may contribute to the observed relationship.

The findings also suggest that gaming exposure should not be considered solely in terms of the amount of time spent gaming. Ergonomic behaviour appeared to be an important component of the relationship between gaming and subsequent symptoms. Prolonged static sitting and infrequent breaks remained associated with incident symptoms after adjustment, suggesting that the way in which gaming exposure is experienced may be relevant in addition to the overall amount of gaming. Sustained postures may result in prolonged loading of particular muscle groups, while infrequent breaks may reduce opportunities for postural variation and recovery. These findings are consistent with previous evidence linking prolonged gaming, sustained postures, and inadequate ergonomic conditions with musculoskeletal problems among gamers and eSports athletes [8,9].

The association between years of gaming and incident symptoms also raises the possibility that cumulative gaming experience may be relevant. Current gaming exposure and years of gaming represent different dimensions of exposure: the former reflects recent gaming intensity, whereas the latter reflects longer-term gaming history. The simultaneous associations observed for these measures may therefore indicate that both current exposure and accumulated experience warrant consideration when examining musculoskeletal health among gamers. However, years of gaming may also be related to other characteristics, such as age, occupational exposure, gaming habits, or changes in gaming behaviour over time. The finding should therefore be interpreted as an association rather than evidence of a cumulative causal effect.

Similar concerns have been reported among Nigerian computer users, where prolonged computer use has been associated with musculoskeletal symptoms [11,12]. However, gaming and general computer use are not equivalent. Gaming may involve different patterns of visual attention, upper-

limb activity, controller or keyboard and mouse use, postural demands, and duration of uninterrupted sessions. Therefore, evidence from general computer users provides contextual support but should not be assumed to directly represent the gaming population.

Overall, the findings support a conceptual distinction between exposure quantity and exposure pattern. The amount of gaming may contribute to musculoskeletal burden, but the manner in which gaming is performed including prolonged static sitting and limited opportunities for breaks may also be relevant. This distinction may be important for future preventive interventions because reducing total gaming time may not be the only potentially relevant strategy; modification of gaming behaviour and the gaming environment may also warrant consideration.

Persistence of Musculoskeletal Symptoms

The persistence of symptoms among participants who were symptomatic at baseline indicates that the musculoskeletal burden observed among gamers may involve both the development of new symptoms and the continuation of existing symptoms. The greater persistence observed among participants with higher gaming exposure provides a basis for further investigation of whether continued exposure contributes to prolonged symptoms. However, the persistence analysis was descriptive and was not designed to establish an independent association or causal relationship.

Persistence may also be influenced by factors beyond gaming exposure, including physical activity, occupational or educational sitting, previous injury, workstation characteristics, symptom severity, access to healthcare, and individual health behaviours. Consequently, the observed persistence should be interpreted as an important descriptive finding rather than evidence that gaming exposure caused symptoms to continue.

Strengths and Limitations

The major strength of this study was its prospective cohort design, which allowed gaming exposure and ergonomic behaviour to be assessed before subsequent musculoskeletal outcomes. This provides stronger temporal evidence than cross-sectional studies, which constitute much of the existing gaming-related literature. The study also distinguished incident symptoms from persistent symptoms and accounted for baseline symptom status when defining the risk set for incident outcomes.

Another strength was the relatively high retention rate during follow-up, which reduced the extent of potential attrition. Nevertheless, the loss of participants to follow-up may still have introduced attrition bias if those who did not complete follow-up differed systematically from those who remained in the study.

Several limitations should be considered. Convenience sampling may limit the generalisability of the findings to the wider Nigerian gaming population. Gaming exposure, ergonomic behaviour, and musculoskeletal symptoms were self-reported and may therefore have been affected by recall or reporting bias. Although the prospective design established temporal sequence, residual confounding cannot be excluded. The ergonomic questionnaire was adapted from the Dutch Musculoskeletal Questionnaire and contextualised to gaming rather than being a fully validated gaming-specific instrument. In addition, changes in gaming exposure and ergonomic behaviour during the follow-up period may have resulted in exposure misclassification because the primary analyses were based on baseline exposure measures.

The number of incident events also limited the statistical power for more complex analyses, including region-specific and interaction analyses. Accordingly, the findings should be interpreted with appropriate caution, particularly where subgroup or interaction effects are concerned. Finally,

while the prospective design strengthens temporal interpretation, it does not by itself establish causality.

Implications and Recommendations

The findings suggest that musculoskeletal health among gamers may be influenced by both the quantity of gaming exposure and the manner in which gaming is performed. Preventive approaches may therefore warrant attention to prolonged static sitting, opportunities for regular breaks, and other modifiable ergonomic behaviours in addition to gaming duration. Future prospective studies should incorporate objective measures of gaming exposure and posture where feasible, use validated gaming-specific ergonomic instruments, and examine changes in exposure and symptoms over multiple follow-up points. Larger studies may also help clarify regional patterns and potential effect modification by gaming characteristics and ergonomic behaviours.

Conclusion

Musculoskeletal symptoms developed in approximately one-third of symptom-free participants during 12 months of follow-up. Higher gaming exposure, longer gaming experience, prolonged static sitting, and infrequent breaks were associated with incident musculoskeletal symptoms after adjustment. More than half of participants with baseline symptoms continued to report symptoms at follow-up. These findings suggest that both cumulative gaming exposure and the ergonomic conditions surrounding gaming may be relevant to musculoskeletal health. Larger prospective and intervention studies are needed to further clarify these relationships and identify effective strategies for prevention.

List of Abbreviations

DMQ – Dutch Musculoskeletal Questionnaire

eSports – Electronic Sports

NMQ-E – Extended Nordic Musculoskeletal Questionnaire

STROBE – Strengthening the Reporting of Observational Studies in Epidemiology

Author Contributions

KEF conceived the study. KEF and AIO contributed to the study design, development of the research questions, and methodology. CNU, AIO, JLE, CUE, UPM and CA contributed to participant recruitment and data collection. KEF conducted the data analysis and drafted the manuscript. All authors contributed to the interpretation of the findings, critically revised the manuscript, read and approved the final version.

Ethics Approval and Consent to Participate

The study received ethical approval from the University of Nigeria Teaching Hospital Health Research Ethics Committee (NHREC/05/01/2008B-FWA00002458-1RB00002323). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before participation.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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Clinical trial number: not applicable.

Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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DATA COLLECTION QUESTIONNAIRE

BASELINE ASSESSMENT

SECTION A: PARTICIPANT INFORMATION AND CONSENT

You are invited to participate in a prospective research study examining whether gaming exposure and ergonomic behaviour are associated with subsequent musculoskeletal symptoms. Participation is voluntary. Your responses will be treated confidentially. A unique study identification number will be assigned so that your baseline and follow-up responses can be linked without using your name in the analytical dataset.

Do you consent to participate?

☐ Yes

☐ No

Participant study ID: _____

Date of baseline assessment: ____ / ____ / ____

SECTION B: SOCIODEMOGRAPHIC INFORMATION

B1. Age: ____ years

B2. Sex:

☐ Male

☐ Female

☐ Prefer not to say

B3. Marital status:

- ☐ Single
- ☐ Married
- ☐ Other: _____

B4. Educational level:

- ☐ Secondary
- ☐ Diploma/NCE
- ☐ Bachelor's degree
- ☐ Postgraduate
- ☐ Other: _____

B5. Employment status:

- ☐ Student
- ☐ Employed
- ☐ Self-employed
- ☐ Unemployed
- ☐ Other: _____

B6. Place of residence: _____

SECTION C: GAMING EXPOSURE

C1. How many years have you been playing video games?

_____ years

C2. On average, how many days per week do you play video games?

_____ days/week

C3. On an average gaming day, how many hours do you spend gaming?

_____ hours/day

C4. On average, how long is one continuous gaming session?

_____ hours/session

C5. What is your primary gaming device?

- ☐ Desktop computer
- ☐ Laptop
- ☐ Smartphone
- ☐ Tablet
- ☐ Gaming console
- ☐ Other: _____

C6. What type of gaming do you primarily participate in?

- ☐ Recreational/casual
- ☐ Competitive/eSports
- ☐ Both
- ☐ Other: _____

C7. What is your gaming status?

- ☐ Professional
☐ Amateur/recreational

C8. Approximately how many hours per week do you spend in organised gaming or training?

_____ hours/week

SECTION D: PHYSICAL ACTIVITY AND OTHER POTENTIAL CONFOUNDERS

D1. Do you regularly participate in physical activity or exercise outside gaming?

- ☐ Yes
☐ No

D2. Number of days of physical activity per week:

_____ days

D3. Average duration per active day:

_____ minutes

D4. Usual intensity:

- ☐ Light
☐ Moderate
☐ Vigorous

D5. Average daily sitting time for work, education or other non-gaming activities:

_____ hours/day

D6. Have you previously experienced a musculoskeletal injury?

- ☐ Yes
☐ No

If yes: _____

D7. Do you regularly experience insufficient sleep or sleep difficulties?

- ☐ Yes
☐ No

SECTION E: GAMING-RELATED ERGONOMIC BEHAVIOUR

Posture

E1. How often do you remain in the same sitting position for a prolonged period while gaming?

- ☐ Never
☐ Rarely
☐ Sometimes
☐ Often
☐ Always

E2. How often do you maintain a sustained neck or trunk posture while gaming?

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

Seating

E3. What type of seat do you normally use?

- ☐ Gaming chair
- ☐ Office/ergonomic chair
- ☐ Ordinary chair
- ☐ Sofa
- ☐ Bed
- ☐ Other

E4. Does the chair provide adequate back support?

- ☐ Yes
- ☐ No

Upper-limb exposure

E5. Are your forearms/elbows adequately supported while gaming?

- ☐ Always
- ☐ Often
- ☐ Sometimes
- ☐ Rarely
- ☐ Never

E6. Do you perform repetitive hand/wrist/finger movements during gaming?

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

Workstation/device arrangement

E7. Is your screen/device positioned approximately at eye level?

- ☐ Yes
- ☐ No
- ☐ Sometimes

E8. Is your gaming workstation arranged to allow a comfortable neck and trunk position?

- ☐ Yes
- ☐ No
- ☐ Sometimes

Break behaviour

E9. Do you take regular breaks during gaming sessions?

- ☐ Yes
- ☐ No

E10. How frequently do you normally take a break?

- ☐ <30 minutes
- ☐ 30–60 minutes
- ☐ 1–2 hours
- ☐ >2 hours

E11. What do you normally do during a break?

- ☐ Stand/walk
- ☐ Stretch
- ☐ Change position
- ☐ Remain seated
- ☐ Other

SECTION F: BASELINE MUSCULOSKELETAL ASSESSMENT

The following questions are based on the Extended Nordic Musculoskeletal Questionnaire. Please indicate whether you currently have or have recently experienced symptoms in each anatomical region.

Anatomical region	Symptoms at baseline?
Neck	☐ Yes ☐ No
Shoulders	☐ Yes ☐ No
Upper back	☐ Yes ☐ No
Lower back	☐ Yes ☐ No
Elbows	☐ Yes ☐ No
Wrists/hands	☐ Yes ☐ No
Hips	☐ Yes ☐ No
Knees	☐ Yes ☐ No
Ankles/feet	☐ Yes ☐ No

For each region with symptoms:

F1. Does the symptom interfere with normal activities?

- ☐ Yes
- ☐ No

F2. Does the symptom interfere with gaming?

☐ Yes

☐ No

F3. Have you sought treatment or medical attention for the symptom?

☐ Yes

☐ No

FOLLOW-UP ASSESSMENT

Participant ID: _____

Date of follow-up: ____ / ____ / ____

SECTION G: CHANGES IN GAMING EXPOSURE

G1. Average gaming days per week since the baseline assessment:

_____ days/week

G2. Average gaming hours per day:

_____ hours/day

G3. Average duration of individual gaming sessions:

_____ hours/session

G4. Has your gaming frequency changed since baseline?

☐ Increased

☐ Decreased

☐ No major change

G5. Has your gaming duration changed since baseline?

☐ Increased

☐ Decreased

☐ No major change

SECTION H: CHANGES IN ERGONOMIC BEHAVIOUR

H1. Has your usual gaming posture changed since baseline?

☐ Yes

☐ No

H2. Has your seating arrangement changed?

☐ Yes

☐ No

H3. Has your workstation/device positioning changed?

☐ Yes

☐ No

H4. Do you now take more regular breaks during gaming?

☐ Yes

☐ No

H5. Has your upper-limb support changed?

- ☐ Improved
☐ Worsened
☐ No change

SECTION I: FOLLOW-UP MUSCULOSKELETAL SYMPTOMS

Using the same assessment procedure as at baseline, indicate whether you have experienced symptoms in each region during the follow-up period.

Anatomical region	Symptom at baseline	Symptom at follow-up
Neck	☐ Yes ☐ No	☐ Yes ☐ No
Shoulders	☐ Yes ☐ No	☐ Yes ☐ No
Upper back	☐ Yes ☐ No	☐ Yes ☐ No
Lower back	☐ Yes ☐ No	☐ Yes ☐ No
Elbows	☐ Yes ☐ No	☐ Yes ☐ No
Wrists/hands	☐ Yes ☐ No	☐ Yes ☐ No
Hips	☐ Yes ☐ No	☐ Yes ☐ No
Knees	☐ Yes ☐ No	☐ Yes ☐ No
Ankles/feet	☐ Yes ☐ No	☐ Yes ☐ No

SECTION J: OUTCOME CLASSIFICATION

For each anatomical region, the research team will classify the participant's outcome as:

Incident symptom:

No symptom at baseline → symptom at follow-up.

Persistent symptom:

Symptom at baseline → symptom remains at follow-up.

Resolved symptom:

Symptom at baseline → no symptom at follow-up.

No symptom:

No symptom at baseline → no symptom at follow-up.