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ORIGINAL ARTICLE

# Patient-reported physical activity and the association with health-related quality of life in head and neck cancer survivors

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**Abstract**
*Purpose* This study aimed to assess patient-reported levels of physical activity (PA) and its associations with health-related quality of life (HRQoL) adjusted for important demographic, lifestyle-related, and clinical factors, among head and neck (HNC) survivors.
*Methods* This cross-sectional study included 116 HNC survivors. PA was assessed with the Physical Activity Scale for the Elderly (PASE) and HRQoL with the EORTC-QLQ-C30 and EORTC-HN35. Associations were studied using univariable and multivariable regression analyses.
*Results* Median PASE score was 100.3 (interquartile range 65.1;170.8) of which 54% were household, 34% leisure-time, and 12% occupational activities. Younger HNC survivors had higher levels of PA. Higher PA was significantly associated with higher global QoL ($p < 0.05$). Findings for physical function, role function, social function, fatigue, and pain were in line, but not statistically significant ($0.05 \leq p < 0.10$).
*Conclusions* Among HNC survivors, a large proportion of PA consists of household activities. Younger HNC survivors had higher PA levels, and higher PA levels were associated with higher HRQoL.

**Keywords** Head and neck neoplasm · Physical activity · Exercise · Physical functioning · Health-related quality of life

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## Introduction

Worldwide, the incidence of head and neck cancer (HNC) has increased over the past decades and 5-year survival rates have improved in Europe [20] and in the USA [29]. As a consequence, more HNC survivors have to cope with physical and psychosocial problems and HNC-specific symptoms associated with cancer and its treatment, such as oral dysfunction, swallowing and speech problems, severely compromising health-related quality of life (HRQoL) [3, 16, 18, 34].

Randomized controlled trials in patients with other types of cancers, mainly breast and prostate cancer, showed that physical activity (PA) can reduce physical and psychosocial problems and improve HRQoL [14, 26, 41]. Observational studies showed that higher levels of moderate-to-vigorous PA are associated with lower mortality risk in survivors of breast, colon, and prostate cancer [19, 21, 25, 30, 38]. Also in HNC survivors, higher pre-treatment levels of PA and physical function were found to be associated with higher HRQoL [6, 36] and survival [10, 43].

However, PA levels of HNC patients tend to decrease following diagnosis and during treatment [9, 32, 36, 40]. Two

previous studies [32, 36] examined demographic, clinical, and lifestyle correlates of PA and had contradictory results. In a sample of 59 HNC survivors, Rogers et al. [32] found that younger age, the absence of comorbidity, and abstinence from alcohol were related to higher levels of patient-reported PA. Sammut et al. [36] found no associations of gender, smoking, comorbidity, and age with weekly energy expenditure after treatment in a sample of 172 HNC survivors. Insight into demographic and clinical correlates of PA may help to identify which subgroups of HNC survivors are more likely to have low PA.

At present, the number of studies evaluating the associations between PA and HRQoL in patients with HNC is scarce, especially as compared to patients with other types of cancer such as breast or prostate [6]. Furthermore, these studies could only include leisure-time PA and no data on household or occupational activities were included. Rogers et al. [32] found higher levels of leisure-time PA, 18.6 (SD 50.9) months after treatment, to be associated with lower fatigue, higher HRQoL, and higher functional wellbeing after adjusting for age, presence of comorbidities, and alcohol consumption. Sammut et al. [36] reported significant positive correlations between higher levels of PA at 12.9 (SD 12.8) months after treatment and higher HRQoL.

Because of the scarcity of evidence regarding PA levels and the association with HRQoL among HNC survivors, the present study aimed to (1) describe the level of PA among HNC survivors, including leisure-time, household, and occupational PA; (2) study demographic, clinical, and lifestyle-related correlates of PA; and (3) assess the association between PA and HRQoL adjusted for important demographic, clinical, and lifestyle-related factors.

## Materials and methods

### Setting and patient recruitment

In this cross-sectional study, patients were recruited between January and September 2013 from the Departments of Otolaryngology-Head and Neck Surgery from VU University Medical Center, Amsterdam, Leiden University Medical Center, and Maastricht University Medical Center. We included data of PA and HRQoL from two separate studies, the OncoQuest study [11] and the OncoKompas [12] study. At the VU University Medical Center, Amsterdam, the OncoQuest system is implemented as part of standard care, to assess HRQoL in patients with HNC. Additionally, the OncoKompas study was launched, which is an online self-management application where cancer survivors can monitor their HRQoL and get tailored feedback and personalized advice on supportive care services. The HRQoL questionnaires we included for the current study were administered before the online self-management application was carried out. The OncoQuest study and the OncoKompas study included the same HRQoL questionnaires. To be able to answer our research questions on PA in HNC survivors and associations with HRQoL, we added the PASE questionnaire for a limited number of time in both studies. Eligibility criteria and patient recruitment of both studies are presented in Fig. 1. Patients were eligible for this cross-sectional study if they were (1) diagnosed with HNC; (2) treated with surgery, radiotherapy, chemoradiation, or a combination of these treatments; (3) aged 18 years or older; and (4) able to write, read, and speak Dutch. Patients were excluded if they were diagnosed with basal cell carcinomas or lymphoma in the head and neck region, or if they suffered from severe psychiatric comorbidities (e.g., schizophrenia, Korsakov's syndrome, severe dementia). All patients signed an informed consent statement prior to participation. The study was conducted according to regular procedures of the local ethical committee of the VU University Medical Center, Amsterdam.

### Outcome measurements

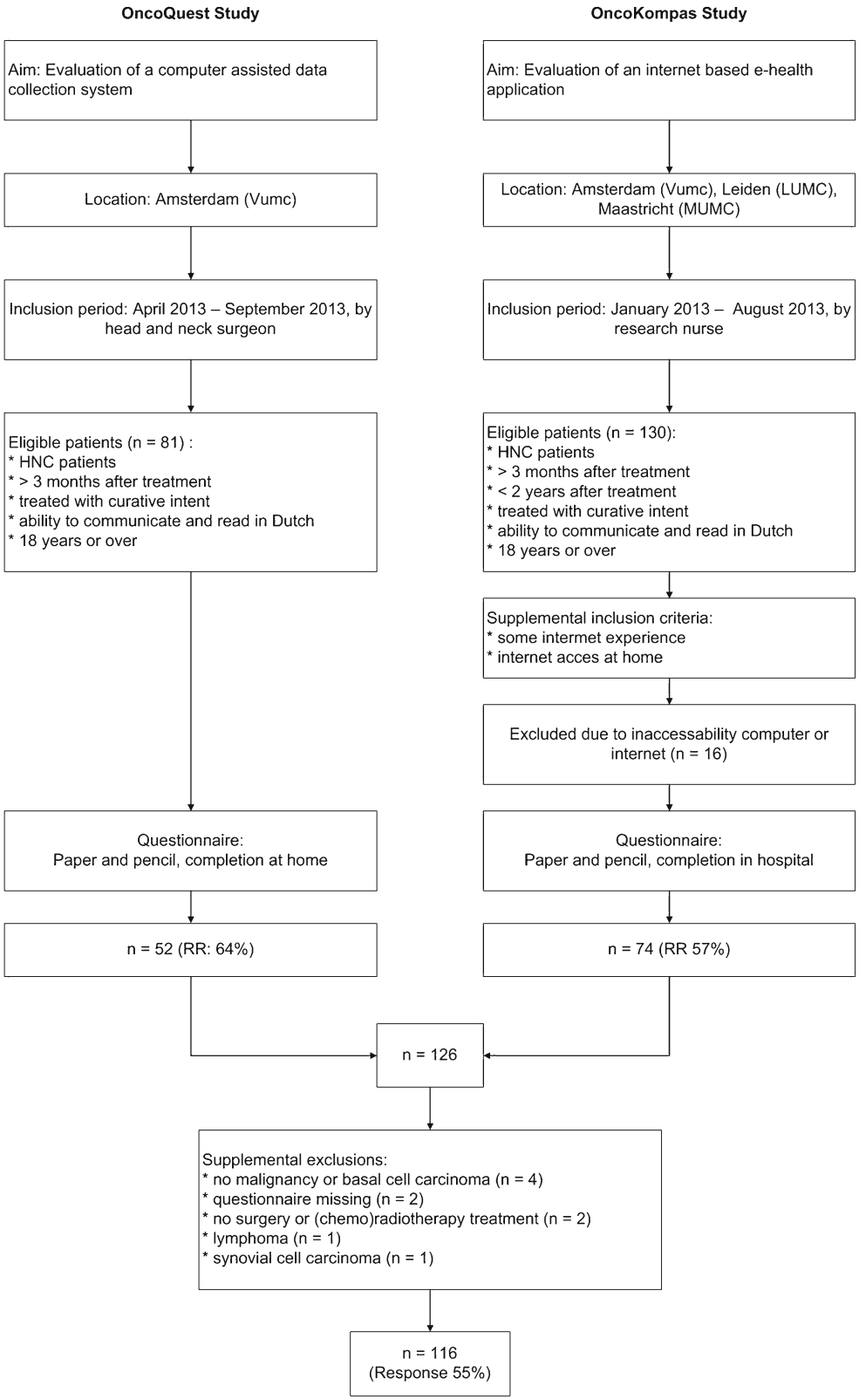
#### *Physical activity*

PA was assessed with the 13-item Physical Activity Scale for the Elderly (PASE), a self-administered 1-week recall questionnaire on leisure-time, household, and occupational physical activities [44]. The frequency of these activities was recorded as never, seldom (1–2 days a week), sometimes (3–4 days a week), or often (5–7 days a week). The duration of activities was categorized as less than 1 h, between 1 and 2 h, between 2 and 4 h, or more than 4 h. Paid or volunteer work, except for work that involved mostly sitting activities such as office work, was categorized as less than 1 h, between 1 and 4 h, between 5 and 8 h, or more than 8 h [45]. The total PASE sum score was computed by multiplying the amount of time spent on each activity (hours/week) by the empirical derived item weights and summing over all activities [39, 44, 45]. The PASE was shown to have good to excellent test-retest reliability, and good content validity among patients with cancer with an average age of 50 (SD 12). Its construct validity (with accelerometers as comparison measure) was comparable to other PA questionnaires [23].

#### *Health-related quality of life*

HRQoL was assessed with the European Organization for Research and Treatment of Cancer (EORTC), quality of life questionnaire core module (EORTC QLQ-C30), and the tumor-specific HRQoL was assessed by the EORTC head and neck module (EORTC HN35) [4]. The EORTC QLQ-C30 is a 30-item questionnaire including a global QoL scale, five

**Fig. 1** Inclusion flowchart




HNC, head and neck cancer; LUMC, Leiden University Medical Center; MUMC, Maastricht University Medical Center; n, number; PRO, patient-reported outcome; RR, response rate; VUmc, VU University medical center

function scales, three symptom scales, and six single items, with higher scores presenting higher global QoL and function, and lower scores presenting higher symptom severity [13]. The EORTC HN35 is a 35-item module including HNC-specific symptom scales and 10 single items covering several problems.

### Demographic, clinical, and lifestyle-related factors

Demographic, clinical, and lifestyle-related factors were collected from medical records and included gender, age, zip codes of patients' living area, smoking (pack years, current smoker), alcohol consumption (units per day, current or former abuse (≥ 5 units a day)), tumor site (oral cavity, oropharynx, hypopharynx, larynx, and other), type (squamous cell carcinoma vs. non-squamous cell carcinoma) and stage (I, II, III and IV), tumor recurrence (dichotomized as none vs. any, including local, regional, and second or third primary tumors), treatment modality (surgery, (chemo)radiotherapy, or surgery followed by (chemo)radiotherapy), time since completion of treatment (months), and comorbidities.

Socio-economic status (SES) was determined using zip codes of patients' living area. Zip codes were translated to SES according to The Netherlands Institute for Social Research [1]. This system describes the social status of a district compared to other districts in The Netherlands using an algorithm based on mean income, percentage of people with low income, percentage of people with low education, and percentage of people with without a job. Therefore, the mean score of all districts in The Netherlands is zero. We dichotomized SES scores to high (> mean value) vs. low (≤ mean value).

Comorbidities were assessed using the Adult Comorbidity Evaluation 27 (ACE-27), a validated chart built instrument examining the presence of any of the following medical conditions: cardiovascular, respiratory, gastro-intestinal, renal, endocrine, neurological, immunological, previous malignancies, psychiatric disorders, alcohol use, and severe overweight, resulting in a total comorbidity score of none, mild, moderate, or severe [28].

### Statistical analysis

Descriptive statistics (mean, standard deviation (SD), or numbers and percentages) were generated for demographic, lifestyle-related, clinical factors, PA and HRQoL. For the continuous variables, median and interquartile range (IQR) were reported when outcomes were not normally distributed (skewness scores $< -1; > 1$). Since total PA score was skewed to the right and the residuals obtained in the regression analysis were not normally distributed, we presented data of total PA as median (IQR) and natural log-transformed the data for analyzing the correlates of PA. We conducted univariable and multivariable linear regression analyses (presenting confidence intervals and standardized regression coefficients) to study demographic, lifestyle-related, and clinical correlates of PA. No multicollinearity (rp > 0.75) was found. To determine the maximum number of variables to be included in the regression model, we used the rule of thumb of 10 patients per determinant. Consequently, our sample of 116 allowed to include a maximum of 11 variable into the regression model. To prevent overfitting in the multiple linear regression model, we selected variables using a forward selection procedure starting with the variable that most strongly predicted PA. Variables were selected one by one and all variables with $p \leq 0.05$ were inserted in the multiple regression model. We back transformed the results from the final model indicating ratios. The associations between PA and HRQoL were assessed using univariable and multivariable linear regression analyses. For the most accurate estimate of the association, we adjusted for demographic, lifestyle-related, and clinical characteristics. Due to the maximum number of variables allowed in the regression model, we have chosen tumor stage over tumor location and tumor type because it is more strongly associated with quality of life [3, 16, 18]. We explored interactions for the main demographic and clinical characteristics (age, gender, cancer stage, and treatment) to study whether the association between PA and HQoL differed between these subgroups. To limit the number of interactions explored, we tested interactions when the associations between PA and HRQOL had a $p$ value < 0.10. $P$ values ≤ 0.05 were considered statistically significant.

## Results

In total, 116 out of 212 HNC survivors met our inclusion criteria and filled out the survey on PA and HRQoL (Fig. 1). Mean (SD) age of participants was 60 (10) years and 63% were men. The most frequent tumor site was oropharynx (26%), followed by oral cavity (22%), larynx (22%), and hypopharynx (7%). Most patients were treated by a combination of treatment modalities (58%). Time since completion of treatment was 21 (21) months. Quality of life scores ranged from 78.2 (global quality of life) to 89.7 (cognitive functioning). Regarding cancer specific HRQoL, symptom scores ranged from 5.1 (social contact) to 24.5 (sexuality, Table 1).

Median (IQR) total PASE score was 100.3 (65.1; 170.8), of which 34% consisted of leisure-time PA, 54% of household activities, and 12% occupational activities. A younger age was significantly associated with higher levels of PA (β = 0.98, 95% CI = 0.96; 1.00) explaining 5.2% of the variance in PA (Table 2, 3). No significant associations with PA were found for other demographic, clinical, or lifestyle-related variables.

After adjusting for age, gender, SES, smoking, alcohol abuse, comorbidity, tumor stage, treatment modality, recurrence, and time since treatment, a higher level of PA was significantly associated with higher global QoL (β: 0.06, 95% CI = 0.03; 0.10). Possible meaningful association were also observed for higher physical function (β: 0.03, 95% CI = −0.00; 0.06), role function (β: 0.04, 95% CI = −0.00;

**Table 1** Demographic, lifestyle-related, and clinical characteristics, physical activity (PA), and health-related quality of life (HRQoL)

| Characteristics | Participants ($n$ = 116) |
|---|---|
| *Demographic factors* | |
| Gender, $n$ (%) male | 73 (63) |
| Age, mean (SD) years | 60 (10) |
| SES, mean (SD) | 0.5 (0.9) |
| High SES (above average), $n$ (%) | 34 (29) |
| *Lifestyle-related* | |
| Smoking (pack years), median (IQR) | 20 (0–40) |
| Smoking at diagnosis, n (%) | 63 (54) |
| Alcohol use (units per day), mean (SD) | 1.5 (2.3) |
| Alcohol abuse[a] at diagnosis, n (%) | 23 (20) |
| *Clinical factors* | |
| Tumor location, $n$ (%) | |
| Oral cavity and oropharynx | 56 (48) |
| Larynx and hypopharynx | 33 (29) |
| Other[b] | 27 (23) |
| Cancer type, $n$ (%) | |
| Squamous cell | 105 (91) |
| Non-squamous cell | 11 (9) |
| Disease Stage, $n$ (%) | |
| I and II | 41 (35) |
| III and IV | 75 (65) |
| Type of treatment, $n$ (%) | |
| Surgery only | 21 (18) |
| Radiotherapy | 28 (24) |
| Chemoradiotherapy | 23 (20) |
| Surgery combined with (chemo)radiation therapy | 44 (38) |
| Recurrence, $n$ (%) | |
| None | 95 (82) |
| Any | 21 (18) |
| Comorbidity, $n$ (%) | |
| None or mild | 74 (64) |
| Moderate or severe | 42 (36) |
| Time since treatment, mediam (IQR) months | 14 (7–23) |
| *Physical activity* | |
| Total score, median (IQR) | 100.3 (65.1–170.8) |
| Leisure-time activities (% of total PA) | 34% |
| Household activities | 54% |
| Occupational activities | 12% |
| *Cancer specific HRQoL, mean (SD)* | |
| Global quality of life | 78.2 (15.9) |
| Physical function | 88.0 (13.7) |
| Role function | 85.5 (19.6) |
| Emotional function | 85.9 (14.0) |
| Cognitive function | 89.7 (14.9) |
| Social function | 85.6 (19.0) |
| Fatigue | 23.9 (21.5) |
| Pain (general) | 14.2 (19.9) |
| Dyspnea | 14.4 (22.9) |
| Insomnia | 16.1 (35.4) |
| Loss of appetite | 6.0 (17.9) |
| Constipation | 9.2 (20.9) |
| Diarrhea | 5.2 (13.6) |
| Financial problems | 9.8 (21.1) |
| Tumor specific HRQoL, mean (SD) | |
| Pain (mouth) | 17.0 (20.9) |
| Swallowing | 16.7 (23.4) |
| Senses | 21.3 (23.4) |
| Speech problems | 16.4 (20.5) |
| Social eating | 15.1 (22.5) |
| Social contact | 5.1 (8.9) |
| Sexuality | 24.5 (29.7) |
| Teeth | 13.9 (24.2) |
| Opening mouth | 13.5 (22.4) |
| Dry mouth | 42.8 (31.3) |
| Sticky saliva | 30.4 (32.3) |
| Coughing | 20.7 (27.3) |
| Feel ill | 9.8 (19.7) |

*CRT* chemoradiation, *n* number, *RT* radiotherapy, *SD* standard deviation, *SES* socio-economic status, *Surg* surgery

[a] Alcohol abuse defined as ≥ 5 units of alcohol per day

[b] Unknown primary, nasopharynx, nasal cavity, nasal sinus, salivary glands, ear, and skin

0.09), social function (β: 0.04, 95% CI = −0.00; 0.09) and lower level of fatigue (β: -0.05, 95% CI = −0.10; 0.00) and less pain (β: -0.04, 95% CI = −0.09; 0.00), but these associations were not statistically significant ($0.05 \leq p < 0.10$, Table 4). Explorative analyses showed that gender was a significant effect modifier in the association between PA and general pain ($\beta_{interaction} = -0.09$, 95% CI = −0.18; −0.005, $p = 0.04$). Explorative stratified analyses for gender revealed a significant association between PA and general pain in women (β = −0.11, 95% CI = −0.19; −0.03, $p = 0.01$), while the association was not statistically significant in men (β = −0.02, 95% CI = −0.07; 0.03, $p = 0.46$). We also found a significant effect modification for age, with a stronger association in patients who were younger ($\beta_{interaction} = 0.005$, 95% CI = 0.00; 0.01, $p = 0.04$).

## Discussion

This cross-sectional study describes self-reported PA levels among HNC survivors, the demographic, lifestyle-related

**Table 2** Demographic, lifestyle-related and clinical correlates of physical activity. Results from univariable regression analyses

| | Ratio (95% CI) | *p* value | Standardized regression coefficients |
|---|---|---|---|
| *Demographic factors* | | | |
| Gender | 1.28 (0.93; 1.77) | 0.13 | 0.14 |
| Age, years | 0.98 (0.96; 1.00) | 0.01 | −0.23 |
| SES | 0.95 (0.68; 1.34) | 0.78 | −0.03 |
| *Lifestyle-related factors* | | | |
| Smoking, pack years | 1.00 (1.00; 1.01) | 0.32 | 0.09 |
| Smoking at diagnosis | 1.20 (0.88; 1.64) | 0.25 | 0.11 |
| Alcohol, units per day | 0.99 (1.07; 1.06) | 0.79 | 0.02 |
| Alcohol abuse[a] | 0.92 (0.62; 1.36) | 0.67 | −0.04 |
| *Clinical factors* | | | |
| Tumor location | | | |
| OC and OP | 1.33 (0.89; 1.98) | 0.16 | 0.17 |
| L and HP | 1.22 (0.78; 1.89) | 0.38 | 0.10 |
| Other | Ref | | |
| Cancer type | 1.51 (0.88; 2.57) | 0.13 | 0.14 |
| Disease Stage | 0.98 (0.70; 1.36) | 0.89 | −0.01 |
| Recurrence | 0.69 (0.46; 1.04) | 0.07 | −0.17 |
| Comorbidity | 0.82 (0.59; 1.14) | 0.23 | −0.11 |
| Type of treatment | | | |
| Single vs. multiple | 0.92 (0.67; 1.27) | 0.62 | −0.05 |
| Time since treatment (months) | 0.99 (0.99; 1.00) | 0.10 | −0.15 |

*CI* confidence interval, *L and HP* larynx and hypopharynx, *OC and OP* oral cavity and oropharynx, *Ref* reference *SES* socio-economic status

[a] Alcohol abuse defined as ≥ 5 units of alcohol per day

Gender (0 = male, 1 = female), SES (0 = other, 1 = high), current smoking (0 = never or former, 1 = current), alcohol abuse (0 = no abuse, 1 = current or former abuse), cancer type (0 = no squamous cell carcinoma, 1 = squamous cell carcinoma), disease stage (0 = stage I and II, 1 = stage III and IV), recurrence (0 = no recurrence, 1 = any recurrence), comorbidity (0 = none or mild, 1 = moderate or severe)

and clinical correlates of PA, and the association between PA and HRQoL. Our median PASE score (100.3, IQR 65.1; 170.8) was comparable to the HNC population ($n$ = 283) in a study from Duffy et al. [9] that reported a mean of 115 pre-treatment and a mean of 106 and 110 at 6 and 9 months after treatment, respectively. However, compared to a non-cancer elderly population also using the PASE questionnaire [44], the population of HNC survivors had lower levels of PA (144.9 vs. 100.3). The findings that HNC survivors are at increased risk for low PA levels and the positive association between PA and HRQoL highlight the relevance for evaluating interventions that aim to improve PA levels in this population [37].

In the study, total PA mainly consisted of household activity (55%). This is comparable with studies in general populations, reporting that 30–60% of total PA consists of household activities [8, 27, 44] and this proportion tends to increase with age [27]. Because of their significant contribution to total PA levels, it is important to also assess household and occupational activities, and not just leisure-time PA as is often the case. Also, for interventions aiming to improve PA levels in HNC survivors, it might be useful to focus on promoting PA during daily routines, especially because HNC survivors reported to prefer exercising alone, unsupervised, and at a moderate intensity [33].

Our finding that older HNC survivors are less physically active is in line with previous studies among HNC survivors [32] as well as in survivors of other types of cancer [2, 5, 15]. This illustrates that it is important to promote PA interventions

**Table 3** Independent correlates of physical activity. Results of the multivariable regression analyses

| | Ratio (95% CI) | *p* value | Standardized regression coefficients |
|---|---|---|---|
| *Demographic factors* | | | |
| Age, years | 0.98 (0.96; 1.00) | 0.01 | −0.23 |

Variables were selected one by one and all variables with $p \leq 0.05$ were inserted in the multiple regression model

**Table 4** The association between physical activity and health-related quality of life (HRQoL)

| | Univariable analyses | *p* value | Multivariable analyses[a] | *p* value |
|---|---|---|---|---|
| HRQoL | β (95% CI) | | β (95% CI) | |
| Global quality of life | 0.059 (0.025; 0.092) | 0.01 | 0.061 (0.025; 0.096) | 0.00 |
| Physical function | 0.034 (0.004; 0.063) | 0.03 | 0.027 (−0.003; 0.057) | 0.08 |
| Role functioning | 0.040 (−0.003; 0.082) | 0.07 | 0.044 (−0.001; 0.089) | 0.05 |
| Emotional functioning | 0.011 (−0.020; 0.042) | 0.49 | 0.004 (−0.030; 0.038) | 0.81 |
| Social functioning | 0.034 (−0.008; 0.075) | 0.11 | 0.043 (−0.002; 0.088) | 0.06 |
| Cognitive functioning | 0.019 (−0.013; 0.052) | 0.24 | 0.018 (−0.019; 0.055) | 0.33 |
| Fatigue | −0.043 (−0.090; 0.04) | 0.07 | −0.050 (−0.103; 0.003) | 0.06 |
| Nausea and vomiting | 0.000 (−0.017; 0.017) | 0.97 | −0.004 (−0.024; 0.015) | 0.65 |
| Pain (general) | −0.050 (−0.092; -0.007) | 0.02 | −0.044 (−0.091; 0.003) | 0.06 |
| Dyspnoe | 0.013 (−0.038; 0.063) | 0.62 | 0.050 (−0.046; 0.056) | 0.84 |
| Insomnia | −0.027 (−0.083; 0.029) | 0.34 | −0.044 (−1.05; 0.017) | 0.15 |
| Loss of appetite | 0.012 (−0.027; 0.052) | 0.54 | 0.001 (−0.042; 0.045) | 0.96 |
| Constipation | −0.026 (−0.072; 0.020) | 0.27 | −0.021 (−0.072; 0.030) | 0.42 |
| Diarrhea | −0.017 (−0.046; 0.013) | 0.27 | −0.019 (−0.053; 0.015) | 0.28 |
| Financial problems | 0.09 (−0.037; 0.056) | 0.67 | 0.016 (−0.036; 0.068) | 0.54 |
| Tumor specific HRQoL | | | | |
| Pain (mouth) | −0.015 (−0.061; 0.031) | 0.53 | −0.009 (−0.060; 0.043) | 0.74 |
| Swallowing | −0.022 (−0.074; 0.029) | 0.39 | −0.022 (−0.073; 0.029) | 0.39 |
| Senses | −0.028 (−0.079; 0.024) | 0.29 | −0.019 (−0.076; 0.038) | 0.51 |
| Speech problems | −0.005 (−0.050; 0.040) | 0.83 | 0.004 (−0.045; 0.054) | 0.86 |
| Social eating | −0.022 (−0.071; 0.027) | 0.38 | −0.021 (−0.071; 0.030) | 0.42 |
| Social contact | −0.008 (−0.028; 0.012) | 0.43 | −0.005 (−0.026; 0.017) | 0.68 |
| Sexuality | −0.037 (−0.105; 0.031) | 0.29 | −0.048 (−0.118; 0.022) | 0.18 |
| Teeth | 0.028 (−0.025; 0.081) | 0.30 | 0.019 (−0.039; 0.077) | 0.51 |
| Opening mouth | −0.031 (−0.080; 0.018) | 0.21 | −0.031 (−0.084; 0.023) | 0.26 |
| Dry mouth | 0.009 (−0.060; 0.078) | 0.80 | 0.001 (−0.073; 0.075) | 0.99 |
| Sticky saliva | 0.005 (−0.066; 0.077) | 0.88 | 0.007 (−0.069; 0.083) | 0.86 |
| Coughing | −0.028 (−0.088; 0.032) | 0.36 | −0.026 (−0.090; 0.038) | 0.42 |
| Feeling ill | −0.018 (−0.061; 0.026) | 0.42 | −0.032 (−0.082; 0.016) | 0.30 |

[a] Adjusted for age, gender, socio-economic status, smoking, alcohol abuse, comorbidity, tumor stage, treatment, recurrence, and time since treatment

in elderly (head and neck) cancer survivors, particularly, because they are at high risk for functional decline after cancer diagnosis [22]. Unfortunately, current interventions to promote PA may not always reach elderly cancer survivors [17]. We found no significant associations regarding PA and other demographic factors (gender and SES) which are comparable to the studies of Rogers et al. [32] and Sammut et al. [36]. However, it should be noted that the information on SES in our study was limited because we estimated SES based on ZIP codes and did not ask patients to provide data on education or income themselves.

In contrast to previous studies, we found no evidence for an association of smoking [5, 15], alcohol consumption [15, 32], or clinical factors with PA [5, 15, 31, 32]. The lack of significant associations for clinical factors (e.g., comorbidity, tumor location, and type of treatment) may indicate that the impact of clinical factors reduces over time and other factors such as motivational factors become more important [7, 24, 31, 42]. Future prospective longitudinal studies with objective PA measurements should further clarify whether these associations (demographic, clinical, and lifestyle-related) might be present in HNC survivors or if these are only present during or shortly after treatment.

Our finding that a higher PA level was associated with higher global QoL, and possibly better physical function, role function, social function, and less fatigue and pain among HNC survivors is consistent with previous studies [32, 36]. This indicates that improving PA might be an intervention target to improve HRQoL. However, due to the cross-sectional design, it is not possible to make causal inferences and it is unclear whether improving PA levels would improve HRQoL, or whether HNC survivors with lower HRQoL are less physically active. In

contrast to general HRQoL, the current study found no support for an association of PA and HNC-specific HRQoL. Due to the cross-sectional nature of this study, it may also suggest that HNC symptoms are not a barrier to PA. Several small studies have shown that PA interventions among HNC survivors are feasible and may improve general and HNC-specific HRQoL [6].

Strengths of our study are the relatively large sample size of an understudied group of cancer survivors, allowing to adjust analysis for important demographic, lifestyle-related, and clinical factors. We could also include levels of PA originating from household or occupational activities in addition to leisure-time PA. However, some limitations must be noted. First, the use of a self-reported questionnaire to assess PA levels is susceptible to recall and social desirability bias [35]. This may have led to an overestimation of PA levels, and therefore the absolute PA level should be interpreted with caution. However, the PASE questionnaire is a valid measure to distinguish active from inactive people [23], and therefore the direction of the associations may be considered valid. Second, we assessed lifestyle-related and clinical factors only at diagnosis, and some of these outcomes might have changed at the time (e.g., smoking, alcohol use, comorbidity) of the questionnaire assessment. Third, the lack of associations of PA with clinical factors may be related to the sample size. However, the wide confidence intervals indicate heterogeneity in the association and standardized regression coefficients were small ($\leq 0.23$), which makes it unlikely that associations will be significant and clinically relevant with larger samples. Finally, the cross-sectional design hampered us to draw conclusions about causality, and future studies are needed to investigate whether increasing PA would improve HRQoL.

In conclusion, in this cross-sectional study we found that HNC survivors, and particularly older survivors, are at risk for low levels of PA. Among HNC survivors, a large proportion of PA consists of household activities. HNC survivors with higher levels of PA had higher global QoL. Future studies should investigate the causality of these associations.

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**Compliance with ethical standards**

**Conflict of interest** All authors declare to have no conflict of interest.

We have full control of all primary data and we agree to allow the journal to review the data if requested.



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