Rheumatology International
https://doi.org/10.1007/s00296-023-05348-9

Rheumatology
INTERNATIONAL

OBSERVATIONAL RESEARCH

High physical activity in persons with psoriatic arthritis is associated with reduced visceral fat mass and percentage body fat: the Trøndelag Health study

Abdirizak Ali Osman[1] · **Mari Hoff**[2,3] · **Vibeke Videm**[1,4,5]

Received: 20 April 2023 / Accepted: 20 May 2023

Abstract

The associations of physical activity (PA) with body composition among persons with psoriatic arthritis (PsA) are not well described. The objective was to investigate associations of PA with visceral fat mass and percentage body fat in persons with PsA of different age groups. Persons with PsA (CASPAR criteria, n = 356), and controls (n = 47,470) from the Trøndelag Health Study (HUNT4, 2017–2019) were included. Visceral fat mass and percentage body fat measured using bioelectrical impedance were primary outcomes in multivariable linear regression analysis. PsA, PA (questionnaire data), and age were explanatory variables, with adjustment for sex, smoking, heart disease, lung disease, and height. An interaction term between PsA and age was included in both models. Persons with PsA had altered body composition, including higher visceral fat mass and percentage body fat, especially those < 40 years of age ($p \leq 0.01$). Moderate or high PA was associated with significantly lower values of the primary outcomes. Differences were Moderate compared to low PA: 1.4 kg (95% CI 1.3, 1.5 kg) lower visceral fat mass, and 2.0% (95% CI 1.8, 2.1) lower percentage body fat. Differences were High compared to low PA: 3.2 kg (95% CI 3.1, 3.3) lower visceral fat mass and 5.0% (95% CI 4.8, 5.1%) lower percentage body fat. Persons with PsA had higher visceral fat mass and percentage body fat, especially if < 40 years, and PA was associated with lower values of both endpoints. Changes of body composition in persons with PsA may influence important health outcomes and should be addressed in clinical practice.

Keywords Psoriatic arthritis · Physical activity · Body composition · Epidemiological study

Introduction

Psoriatic arthritis (PsA) is an autoimmune, inflammatory disease characterized by skin and joint involvement. The prevalence of PsA among persons with psoriasis is estimated to 15–30% [1, 2]. Clinical manifestations include peripheral and axial arthritis, enthesitis (inflammation at the sites where ligaments and tendons attach to bones), and dactylitis (inflammation of an entire digit) [3]. As PsA is classified as a spondyloarthropathy, it is also associated to uveitis and colitis. Apart from these manifestations, PsA is associated with comorbidities including the metabolic syndrome, diabetes, obesity, hyperlipidemia, hypertension, and insulin resistance, which significantly increase the risk of cardiovascular disease (CVD) morbidity and mortality [4–9]. Studies suggest that persons with PsA are less physically active [10] and have high prevalence of obesity [11] compared to the general population. Both low physical activity (PA) and obesity are

✉ Vibeke Videm
vibeke.videm@ntnu.no

1 Department of Clinical and Molecular Medicine, NTNU - Norwegian University of Science and Technology, Trondheim, Norway

2 Department of Neuromedicine and Movement Science, NTNU - Norwegian University of Science and Technology, Trondheim, Norway

3 Department of Rheumatology, St. Olavs University Hospital, Trondheim, Norway

4 Department of Immunology and Transfusion Medicine, St. Olavs University Hospital, Trondheim, Norway

5 Department of Clinical and Molecular Medicine, St. Olavs University Hospital, Lab Center 3 East, 7006 Trondheim, Norway

Published online: 05 June 2023

known risk factors of CVD. Moreover, obesity increases the risk of developing PsA [12, 13].

Because of the high prevalence of obesity in persons with PsA, there has been an increasing interest in investigating their body composition. A systematic review showed that persons with PsA have an altered body composition, including higher visceral fat mass and percentage body fat compared to the general population [14]. Adipose tissue is a hormonally active organ, secreting adipokines, including tumor necrosis factor-α (TNF-α), leptin, resistin, and IL-6, which promote systemic inflammation and increase the risk of several pathophysiological conditions [15–17]. Having higher visceral fat mass is associated with increased risk of the metabolic syndrome [18], type 2 diabetes [19], CVD [20], non-alcoholic fatty liver disease [21], different types of cancer [22–24] as well as all-cause mortality [25], whereas having less visceral fat mass is associated with favorable health outcomes [26, 27].

Since body composition is modifiable in clinical practice, it is important to design proper interventions that could reduce visceral fat mass and percentage body fat in persons with PsA.

One such non-invasive intervention is PA. Although PA has well-established health benefits, its effects on body composition in persons with PsA is less investigated. A randomized controlled trial of 61 persons with PsA showed reduction of visceral fat after performing high-intensity interval training for 11 weeks [28]. However, because of the small sample size and lack of other studies, the generalizability of these results is not established.

We therefore performed a large population-based study aimed at investigating the relationship between visceral fat mass and percentage body fat, respectively, with PA in persons with PsA compared to controls. We also aimed to determine age-related differences of visceral fat mass and percentage body fat in persons with PsA and controls. Our hypothesis was that increased PA was associated with reduced visceral fat mass and percentage body fat, and that the alteration of body composition develops early in life, thus contributing to the comorbidity burden among persons with PsA. Furthermore, we performed an exploratory analysis to investigate the association between waist circumference and visceral fat mass. The exploratory aim was to evaluate whether waist circumference measurements could be used to estimate the amount of visceral fat mass in clinical practice.

Methods

This retrospective analysis of cross-sectional case–control data utilized data from the fourth survey of the Trøndelag Health Study (HUNT4, 2017–2019) [29]. The present study is part of HuLIAS (HUNT Longitudinal Inflammatory Arthritis Study).

Patients

The study included persons with PsA (n = 356), and controls (n = 47,470) with complete data for relevant variables in HUNT4. The inclusion criterion was participation in HUNT4. The exclusion criteria were missing information on PsA status or being given a PsA diagnosis within 1 year following HUNT4 participation, missing data for visceral fat mass and/or percentage body fat, and missing data for adjustment variables in the multivariable analysis, as detailed in Fig. 1. To diagnose PsA, data from HUNT4 were merged with medical records from two local hospitals, Levanger and Namsos hospitals, as well as the university hospital in Trondheim, St. Olavs Hospital. The medical records of persons with a probable PsA diagnosis were evaluated by an experienced senior rheumatologist (MH) using the ClASsification for Psoriatic ARthritis (CASPAR) criteria [30].

Main outcome variable

The main outcome variables were visceral fat mass in kg and percentage body fat, measured in HUNT4 with bioelectrical impedance analysis with eight tactile electrodes (InBody770; Biospace, Tokyo, Japan). The device is based on the 4-compartment model (total body water, proteins, minerals, and body fat) and uses 6 frequencies (1, 5, 50, 250, 500, and 1000 kHz).

Study factors

Explanatory variables of the models included PsA (yes/no), age (categorized into 3 categories: < 40, 40–59 and > 60 years, because of a non-linear association of age with the primary endpoints), and PA quantified based on self-reported questionnaire data. As in previous surveys, HUNT4 included 3 questions regarding PA, covering frequency (categories ranging from "never" to "almost every day"), duration (categories ranging from "< 15 min" to "> 1 h per session"), and intensity (categories ranging from "take it easy" to "push near exhaustion") [31]. The replies were aggregated in two alternative ways: (1) using a summary index developed in the HUNT fitness sub-study with weighting of the responses [31], and categorizing the index values as low, moderate, or high PA, or (2) according to whether participants fulfilled the well-supported recommendations from the American College of Sports Medicine/American Heart Association for aerobic PA for healthy adults [32]. The recommendations are moderate intensity PA ≥ 30 min on five days a week or vigorous intensity

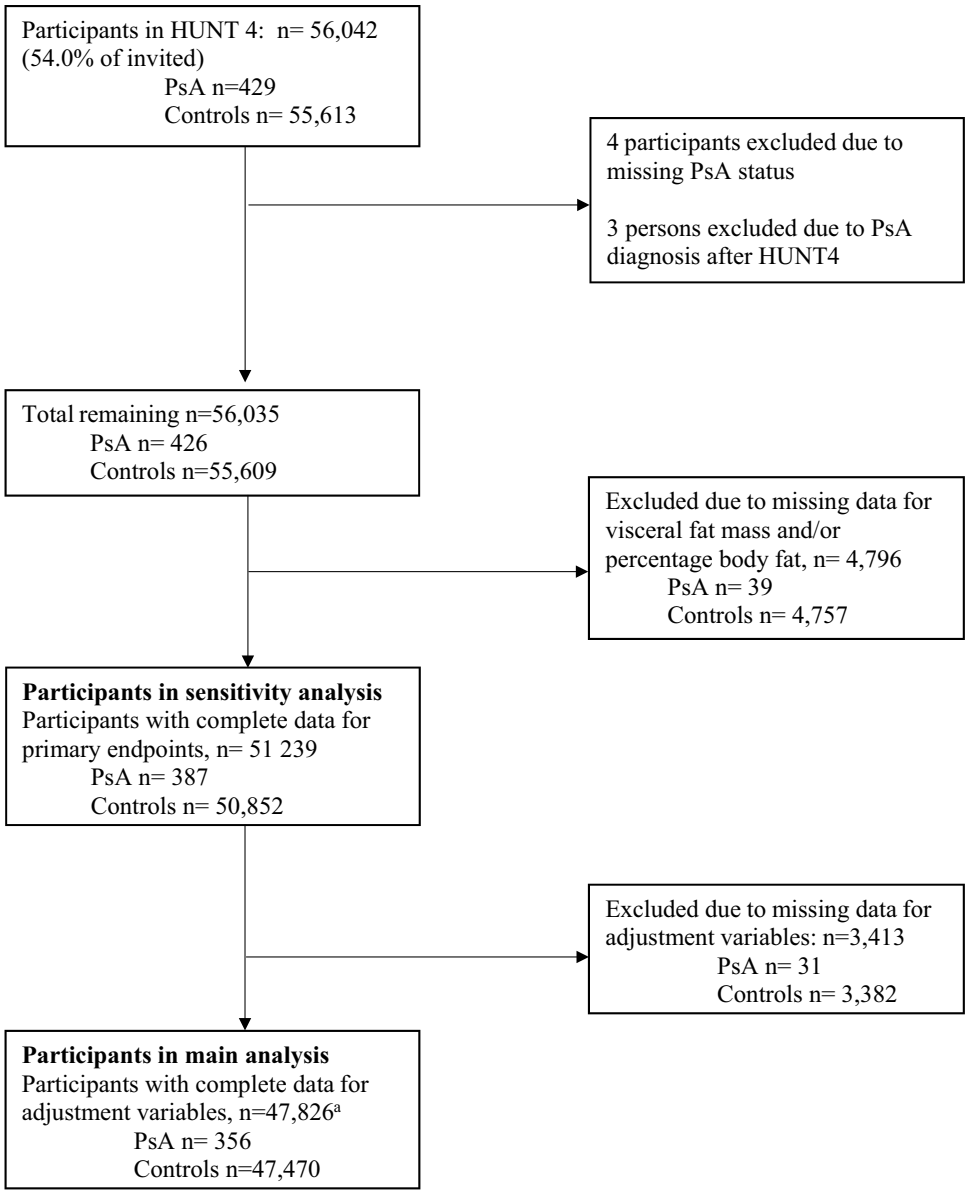

Fig. 1 Participant inclusion and exclusion to the present study. [a]missing data for sex n = 0, smoking n = 275, lung diseases n = 1728, heart disease n = 1859 and physical activity index n = 1437

aerobic PA ≥ 20 min on three days a week, or combinations to meet these criteria.

Other variables

The statistical models for visceral fat mass and percentage body fat were adjusted for predefined variables influencing both PA and the primary endpoints, known from the literature and available in HUNT4. Adjustment variables included sex, self-reported smoking status (present, former, or never smoker), heart disease (yes/no, yes = myocardial infarction or heart failure), lung disease (yes/no, yes = chronic obstructive lung disease or asthma), and height to account for differences in body size.

Procedures

HUNT is an open population-based cohort study carried out in the northern part of Trøndelag county, Norway [29]. All inhabitants ≥ 20 years of age were invited to participate. The fourth survey (HUNT4, 2017–2019, n = 56,042, i.e. 54% of those invited) consisted of questionnaires, interviews, clinical measurements, and analysis of blood samples. Participants in HUNT gave written informed consent. The study was approved by the Regional Committee for Medical and Health Research Ethics, Northern Norway (#11926) on 4/25/2019. The study was performed in accordance with the Helsinki Declaration.

Statistical analysis

The distribution of the data was evaluated using histograms. Data are given as number with frequencies or means with standard deviation. Persons with PsA and controls were compared using Pearson's chi-squared test, the Mann Whitney Wilcoxon Test, or the t-test depending on the distribution of the variable.

Associations of the explanatory variables with the endpoints were analyzed with multivariable linear regression. In the models, PA was evaluated as low, moderate, or high based on the index calculated from self-reported PA frequency, duration, and intensity, because this variable gave better model fit. To investigate whether body composition in persons with PsA compared to controls differed according to age, an interaction term between PsA and age group was tested in the models. We used robust estimation of standard errors. Assumptions of multivariable linear regression and model fit, including linear relationships between predictors and the outcomes and normality of the residuals were evaluated using plots. As a sensitivity analysis to evaluate whether the results were biased due to analysis of complete cases for the adjustment variables, multiple imputation of missing data was performed. We used chained equations (n = 150 data sets), assuming "missing at random".

To investigate the correlation between visceral fat mass and waist circumference, a simple linear regression analysis with visceral mass (dependent variable) and waist circumference (independent variable) was performed. Statistical analyses were performed using Stata (v. 16.1 StataCorp. College Station, TX, USA). P-values < 0.05 were considered statistically significant.

Results

The study included n = 356 persons with PsA and n = 47,470 controls. Participant characteristics are given in Table 1. Persons with PsA were older and more often unemployed at the time of research compared to controls. They also had significantly higher prevalences of diabetes, cancer, and hypertension, as well as higher levels of serum triglycerides and cholesterol. Persons with PsA were less physically active according to the recommendations for PA (Table 2) and were more often smokers. They had also higher weight, body mass index, visceral fat mass, percentage body fat, and waist-hip ratio.

The regression model for visceral fat mass ($R^2 = 0.15$) showed that having a diagnosis of PsA was associated with a mean increase in visceral fat mass of 2.0 kg (95% CI 1.2, 2.8 kg). Table 3 gives the coefficients for variables in the model. Moderate and high PA were significantly associated with lower visceral fat mass both for persons with PsA and controls. Moderate PA was associated with 1.4 kg (95% CI 1.3, 1.5 kg), and high PA with 3.2 kg (95% CI 3.1, 3.3) lower visceral fat mass compared to low PA.

The model for percentage body fat ($R^2 = 0.38$) showed that a diagnosis of PsA was associated with a mean increase in percentage body fat of 2.7% (95% CI 1.6, 3.8, Table 3) Moderate or high PA was significantly associated with lower values of percentage body fat both for persons with PsA and controls. Moderate PA was associated with 2.0% (95% CI 1.8, 2.1) and high PA was associated with 5.0% (95% CI 4.8, 5.1%) lower percentage body fat compared to low PA.

The interaction term between PsA and age groups was statistically significant for both models (visceral fat mass: p = 0.026, percentage body fat: p = 0.013). The difference in visceral fat mass in individuals with PsA compared to controls of the same age group was relatively larger in persons < 40 years (visceral fat mass difference in persons < 40 years: 4.9 kg (95% CI 1.9, 7.9 kg) vs. 1.2 kg (95% CI 0.1–2.4) in age group 40–69 years and 1.4 kg (95% CI 0.2, 2.5 kg) in age 60 years and above (Fig. 2a). The difference in percentage body fat was also higher in persons with PsA < 40 years (percentage body fat difference in persons < 40 years, 5.2% (1.9, 8.5) vs. 1.2 kg (95% CI 0.1–2.4) in age group 40–69 years and 1.4 kg (95% CI 0.2, 2.5 kg) in age 60 years and above (Fig. 2b).

Results from the sensitivity analysis in the complete dataset following multiple imputation of missing data gave very similar results as the main analysis and thus confirmed that the results were not biased by excluding the participants with missing data.

The simple linear regression model of visceral fat mass and waist circumference was statistically significant ($R^2 = 0.75$, p < 0.001), illustrating that waist circumference measurements could estimate the values of visceral fat mass. However, the estimation was not precise as seen in a scatterplot (Online Resource 1—Scatterplot of waist circumference and visceral fat mass). The mean difference between the predicted and observed values was 2.8 kg.

Discussion

The present study showed that moderate and high PA were significantly associated with lower visceral fat mass and percentage body fat both in persons with PsA and controls. However, PsA was associated with higher values of visceral fat mass and percentage body fat compared to controls. The greatest differences compared to controls of the same age group were seen among persons with PsA < 40 years of age.

The present study strengthens the evidence of body composition alterations in persons with PsA and supports previous studies [14, 28, 33–38]. A few studies with small sample sizes did not find these associations [39, 40]. The

Table 1 Demographic and clinical characteristics

Variable	PsA, n = 356	Controls, n = 47,470	p-value
Age years, mean (SD)	58 (12)	53 (17)	p < 0.001
Age at PsA diagnosis years, mean (SD)	46 (11)	–	
Years with PsA diagnosis at time of study participation[a]		–	–
9 years or less, n (%)	20 (9)		
10–19 years, n (%)	115 (54)		
20 years and above, n (%)	78 (37)		
Male, n (%)	200 (56)	25,731 (54)	p = 0.46
Diabetes[b], n (%)	35 (10)	2440 (5)	p < 0.001
Heart disease[c], n (%)	19 (5)	1753 (4)	p = 0.10
Hypertension[d], n (%)	169 (47)	17,188 (36)	p < 0.001
Respiratory disease[e], n (%)	50 (14)	6200 (13)	p = 0.58
Hypercholesterolemia, n (%)	79 (22)	9443 (20)	p = 0.30
Cancer, n (%)	35 (10)	3281 (7)	p = 0.033
Serum triglycerides mmol/L, mean (SD)	1.9 (1.2)	1.6 (1.0)	p < 0.001
HDL cholesterol mmol/L, mean (SD)	1.4 (0.4)	1.4 (0.4)	p = 0.98
Systolic blood pressure mmHg, mean (SD)	130 (18)	128 (18)	p = 0.033
Diastolic blood pressure, mmHg, mean (SD)	74 (10)	73 (10)	p = 0.25
CRP mg/L, mean (SD)	4 (6)	3 (5)	p < 0.001
eGFR ml/min/1.73m^2, mean (SD)	91 (16)	93 (19)	p = 0.034
Alcohol (twice a week or more), n (%)	78 (22)	9623 (20)	p = 0.45
Smoking status, n (%)			p < 0.001
Present	58 (16)	4688 (10)	
Former	201 (57)	21,567 (45)	
Never	97 (27)	21,215 (45)	
Education (approved apprenticeship, college or higher), n (%)	195 (55)	29,711 (63)	p = 0.002
Unemployed at the time of HUNT4 participation, n (%)	163 (46)	16,473 (35)	p < 0.001

PsA psoriatic arthritis, *HDL* high-density lipoprotein, *CRP* C-reactive protein, *eGFR* estimated glomerular filtration rate, *HUNT4* the 4th survey of the longitudinal population-based Trøndelag Health Study

[a]143 persons with PsA were missing the year of diagnosis

[b]Diabetes: self-reported diabetes

[c]Heart disease: myocardial infarction or heart failure; self-reported

[d]Hypertension: systolic blood pressure ≥ 140 mm Hg and/or a diastolic blood pressure ≥ 90 mm Hg and/or the use of antihypertensive medication

[e]Respiratory disease: self-reported asthma and/or chronic obstructive pulmonary disease

reasons for the body composition changes are thought to be complex involving genetic disposition, disease pathophysiology, medications, as well lifestyle factors such as PA and diet [14, 41–43].

Our study further showed that persons with PsA < 40 years had the highest values for visceral fat mass and percentage body fat compared to controls of the same age group. Since these persons are expected to live longer, the negative impacts of visceral fat mass and percentage body fat may compound over several decades, contributing the comorbidity burden observed among persons with PsA. The reasons for the body composition changes in persons with PsA < 40 years are not known. However, a population-based study in Sweden showed that younger women with spondylarthritis including PsA tended to be less compliant with the WHO recommendations for PA [44]. This suggests that low PA may be a potential explanatory factor. Longitudinal studies are therefore needed to investigate the reasons and impacts of the body composition changes in young persons with PsA.

The present study also showed that persons with PsA were less physically active according to the recommendations of PA for adults [32]. These findings are in accordance with the results of many studies that demonstrate low PA in persons with PsA [10, 41]. Systemic inflammation is regarded as a link between PsA and CVD [18], and PA

Table 2 Body composition and physical activity

Variable	PsA, n = 356	Controls, n = 47,470	p-value
Height cm, mean (SD)	171 (9)	171 (9)	p = 0.65
Weight kg, mean (SD)	84 (17)	80 (16)	p < 0.001
Body mass index kg/m^2, mean (SD)	28.6 (4.7)	27.2 (4.7)	p < 0.001
Waist-hip ratio, mean (SD)	0.99 (0.1)	0.96 (0.1)	p < 0.001
Body fat mass kg, mean (SD)	28.8 (11)	25.2 (11)	p < 0.001
Percentage body fat, mean (SD)	33.8 (8.7)	30.9 (9.4)	p < 0.001
Visceral fat mass kg, mean (SD)	13.7 (5.5)	11.7 (5.5)	p < 0.001
Physical activity index			p = 0.14
Low	204 (57)	24,949 (53)	
Moderate	104 (29)	14,636 (31)	
High	48 (14)	7885 (16)	
Did not meet the recommended level of physical activity[a], n (%)[2]	201 (61)	25,674 (56)	p = 0.047

PsA psoriatic arthritis

[a]Recommendations of physical activity for adults from the American College of Sports Medicine /American Heart Association [32]

Table 3 Regression analysis of visceral fat mass and percentage body fat

Variable	Visceral fat mass (kg)		Percentage body fat	
	Regression coefficient (Standard error)	p-value	Regression coefficient (Standard error)	p-value
PsA	4.0 (1.1)	p < 0.001	5.2 (1.9)	p = 0.006
Age group				
20–39 years	Reference		Reference	
40–59 years	2.1 (0.1)	p < 0.001	3.1 (0.1)	p < 0.001
60 years and above	3.1 (0.1)	p < 0.001	4.5 (0.1)	p < 0.001
Interaction between PsA and age group[a]	− 2.6 (1.4)	p = 0.026	− 3.8 (1.8)	p = 0.013
Female sex	− 3.3 (0.1)	p < 0.001	− 7.6 (0.1)	p < 0.001
Physical activity index				
Low	Reference		Reference	
Moderate	− 1.4 (0.1)	p < 0.001	− 2.0 (0.1)	p < 0.001
High	− 3.2 (0.1)	p < 0.001	− 5.0 (0.1)	p < 0.001

The models were adjusted for sex, smoking status, heart disease, lung disease, and height

PsA psoriatic arthritis

[a]Age groups were coded as 0 = 20–39 years, 1 = 50–59 years, and 2 = 60 years and above

is acknowledged to reduce both chronic inflammation [45] and CVD [46] in the general population. Therefore, the low PA levels in persons with PsA may lead to increased CVD morbidity and mortality and should be addressed in clinical settings.

Moderate or high PA was associated with reduced levels of visceral fat mass and percentage body fat both in persons with PsA and controls. Because of the cross-sectional design of the present study, it was not possible to determine causality. However, several studies in the general population [47], as well as a small study of persons with PsA [28] indicated a causal relationship. In these studies, higher PA levels led to favorable changes in body composition in terms of reduced visceral fat mass and overall body fat. To our knowledge, the present study is the first that examined the association of PA with visceral fat mass and percentage body fat in a population-based setting.

The exploratory analysis showed that waist circumference was significantly positively correlated with visceral fat mass. In clinical practice, measuring waist circumference is relatively easy even if accuracy may depend on body shape, and may estimate the amount of visceral fat mass. However, our study clearly demonstrated that these

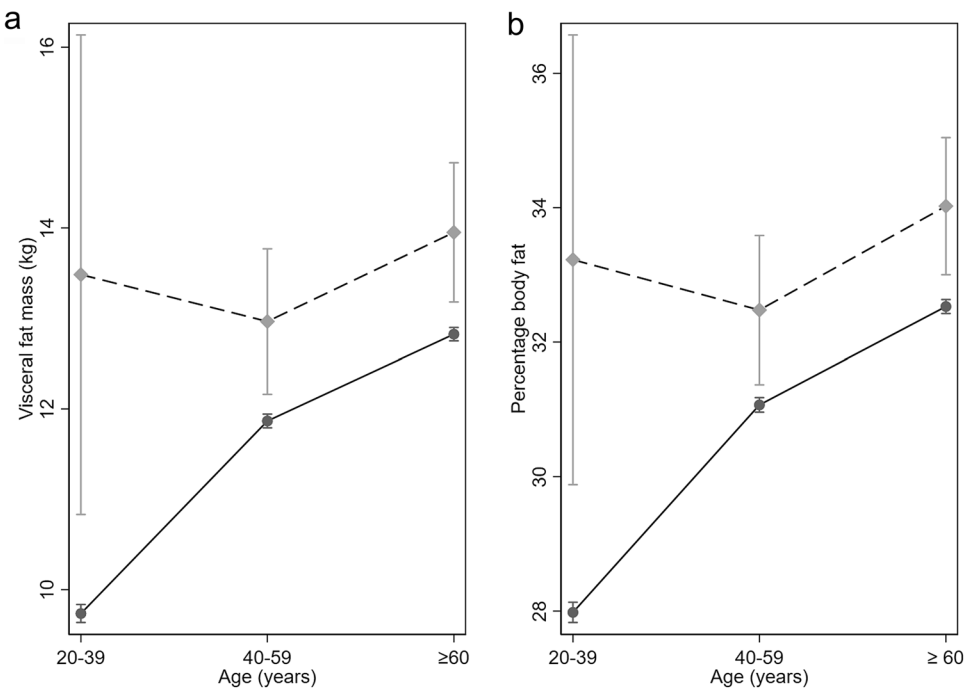

Fig. 2 Interaction effects with age. **a** Visceral fat mass in participants with psoriatic arthritis and controls in different age groups (mean with 95% confidence interval). **b** Percentage body fat in participants with psoriatic arthritis and controls in different age groups (mean with 95% confidence interval)

measurements are not precise, and their limitations should be acknowledged in clinical practice.

The study has several strengths. Bioelectrical impedance analysis was used to measure body composition, which is more precise than anthropometric measurements such as BMI, skinfold thickness, waist and hip circumference, and hip-waist ratio. Body composition can be measured with several non-anthropometric methods including bioelectrical impedance analysis, dual-energy X-ray absorptiometry, and computer tomography. As of today, there is no consensus on the optimal advanced assessment method of body composition among persons with PsA [48], giving challenges both in research and clinical practice [14]. Therefore, it is important to standardize the methods to be able to compare different data regarding body composition.

Another strength of the study was the large number of participants in a population-based study, as well as validated PsA diagnoses. The findings of the study are therefore more likely to be applicable in the general population.

The study also has limitations. The use of self-reported PA may lead some persons with PsA to overestimate the intensity of PA levels because they experience joint pain or fatigue. Another limitation of the study is that bioelectrical impedance analysis may underestimate the percentage body fat it in obese participants [49]. This may apply to persons with PsA in our study since they had significantly higher weight than controls.

In conclusion, the present study showed that moderate and high PA was associated with lower values of visceral fat mass and percentage body fat both in persons with PsA and controls. Persons with PsA had higher visceral fat mass and percentage body fat compared to controls of their age group, especially persons with PsA < 40 years. They were also less compliant with the recommended PA levels. The study emphasizes the importance of screening the body composition of persons with PsA and evaluate factors contributing to these changes. Low PA levels among persons with PsA may lead to changes in body composition and influence important health outcomes, and should be addressed in clinical settings.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00296-023-05348-9.

Acknowledgements The Trøndelag Health Study (HUNT) is a collaboration between the HUNT Research Centre, NTNU—Norwegian University of Science and Technology, Trøndelag County Council, Central Norway Regional Health Authority, and the Norwegian Institute of Public Health. Preliminary results from the study were presented at the EULAR annual conference in 2022 (Osman AA, Hoff M, Videm V (2022) POS0313 The association between body composition and physical activity in patients with psoriatic arthritis: The Trøndelag Health Study. Ann Rheum Dis 81:407. https://ard.bmj.com/content/81/Suppl_1/407.1).

Author contributions AAO contributed to the study conception and design, performed data analysis, wrote the first manuscript draft, and contributed to interpretation of the results and critical revision for important intellectual content. MH contributed to the study conception and design, interpretation of the results, and critical revision for important intellectual content. VV contributed to the study conception and design, performed data analysis, and contributed to interpretation of the results and critical revision for important intellectual content. All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding Open access funding provided by NTNU Norwegian University of Science and Technology (incl St. Olavs Hospital - Trondheim University Hospital). The study was funded by the faculty of Medicine and Health Sciences at NTNU—Norwegian University of Science and Technology (project #980004261).

Open data sharing Data from HUNT are available upon reasonable request from the HUNT Research Centre (www.ntnu.edu/hunt/data), following approval from the Regional Ethics Committee. However, restrictions apply to the availability of the data for the present paper, which were used under license for the current study and are not publicly available in accordance with Norwegian law.

Declarations

Conflict of interest Author MH has received a speaker honorarium from Company AbbVie and Company Janssen Pharmaceuticals. Author AAO and Author VV declare that they have no conflict of interest.

Ethical approval The study was performed in accordance with the Helsinki Declaration and was approved by the Regional Committee for Medical and Health Research Ethics, Northern Norway (#11926) on 4/25/2019. All participants gave informed consent.

References

1. Villani AP, Rouzaud M, Sevrain M et al (2015) Prevalence of undiagnosed psoriatic arthritis among psoriasis patients: systematic review and meta-analysis. J Am Acad Dermatol 73:242–248. https://doi.org/10.1016/j.jaad.2015.05.001
2. Prey S, Paul C, Bronsard V et al (2010) Assessment of risk of psoriatic arthritis in patients with plaque psoriasis: a systematic review of the literature. J Eur Acad Dermatol Venereol 24:31–35. https://doi.org/10.1111/j.1468-3083.2009.03565.x
3. Ritchlin CT, Colbert RA, Gladman DD (2017) Psoriatic arthritis. N Engl J Med 376:957–970. https://doi.org/10.1056/nejmra1505557
4. Ogdie A, Schwartzman S, Husni ME (2015) Recognizing and managing comorbidities in psoriatic arthritis. Curr Opin Rheumatol 27:118–126. https://doi.org/10.1097/bor.0000000000000152
5. Gupta S, Syrimi Z, Hughes DM, Zhao SS (2021) Comorbidities in psoriatic arthritis: a systematic review and meta-analysis. Rheumatol Int 41:275–284. https://doi.org/10.1007/s00296-020-04775-2
6. Gladman DD, Ang M, Su L, Tom BDM, Schentag CT, Farewell VT (2009) Cardiovascular morbidity in psoriatic arthritis. Ann Rheum Dis 68:1131–1135. https://doi.org/10.1136/ard.2008.094839
7. Gulati AM, Semb AG, Rollefstad S, Romundstad PR, Kavanaugh A, Gulati S, Haugeberg G, Hoff M (2016) On the HUNT for cardiovascular risk factors and disease in patients with psoriatic arthritis: population-based data from the Nord-Trøndelag Health Study. Ann Rheum Dis 75(5):819–824. https://doi.org/10.1136/annrheumdis-2014-206824
8. Zhu TY, Li EK, Tam L-S (2012) Cardiovascular risk in patients with psoriatic arthritis. Int J Rheumatol. https://doi.org/10.1155/2012/714321
9. Verhoeven F, Prati C, Demougeot C, Wendling D (2020) Cardiovascular risk in psoriatic arthritis, a narrative review. Joint Bone Spine 87:413–418. https://doi.org/10.1016/j.jbspin.2019.12.004
10. Kessler J, Chouk M, Ruban T, Prati C, Wendling D, Verhoeven F (2021) Psoriatic arthritis and physical activity: a systematic review. Clin Rheumatol 40:4379–4389. https://doi.org/10.1007/s10067-021-05739-y
11. Queiro R, Lorenzo A, Tejón P, Coto P, Pardo E (2019) Obesity in psoriatic arthritis: comparative prevalence and associated factors. Medicine (Baltimore) 98:e16400. https://doi.org/10.1097/md.0000000000016400
12. Thomsen RS, Nilsen TIL, Haugeberg G, Gulati AM, Kavanaugh A, Hoff M (2021) Adiposity and physical activity as risk factors for developing psoriatic arthritis: longitudinal data from a population-based study in Norway. Arthritis Care Res 73:432–441. https://doi.org/10.1002/acr.24121
13. Love TJ, Zhu Y, Zhang Y, Wall-Burns L, Ogdie A, Gelfand JM, Choi HK (2012) Obesity and the risk of psoriatic arthritis: a population-based study. Ann Rheum Dis 71:1273–1277. https://doi.org/10.1136/annrheumdis-2012-201299
14. Blake T, Gullick NJ, Hutchinson CE, Barber TM (2020) Psoriatic disease and body composition: a systematic review and narrative synthesis. PLoS ONE 15:e0237598. https://doi.org/10.1371/journal.pone.0237598
15. Mathieu P, Poirier P, Pibarot P, Lemieux I, Després JP (2009) Visceral obesity: the link among inflammation, hypertension, and cardiovascular disease. Hypertension 53:577–584. https://doi.org/10.1161/hypertensionaha.108.110320
16. Pi-Sunyer FX (1999) Comorbidities of overweight and obesity: current evidence and research issues. Med Sci Sports Exerc 31:S602. https://doi.org/10.1097/00005768-199911001-00019
17. Harwood HJ (2012) The adipocyte as an endocrine organ in the regulation of metabolic homeostasis. Neuropharmacology 63:57–75. https://doi.org/10.1016/j.neuropharm.2011.12.010
18. Ritchie SA, Connell JMC (2007) The link between abdominal obesity, metabolic syndrome and cardiovascular disease. Nutr Metab Cardiovasc Dis 17:319–326. https://doi.org/10.1016/j.numecd.2006.07.005
19. Björntorp P, Rosmond R (1999) Visceral obesity and diabetes. Drugs 58:13–18. https://doi.org/10.2165/00003495-199958001-00005
20. Mathieu P, Pibarot P, Larose E, Poirier P, Marette A, Després JP (2008) Visceral obesity and the heart. Int J Biochem Cell Biol 40:821–836. https://doi.org/10.1016/j.biocel.2007.12.001
21. Hanlon CL, Yuan L (2022) Nonalcoholic fatty liver disease: the role of visceral adipose tissue. Clin Liver Dis (Hoboken) 19:106–110. https://doi.org/10.1002/cld.1183
22. Von Hafe P, Pina F, Pérez A, Tavares M, Barros H (2012) Visceral fat accumulation as a risk factor for prostate cancer. Obes Res 12:1930–1935. https://doi.org/10.1038/oby.2004.242
23. Schapira DV, Clark RA, Wolff PA, Jarrett AR, Kumar NB, Aziz NM (1994) Visceral obesity and breast cancer risk. Cancer 74:632–639. https://doi.org/10.1002/1097-0142(19940715)74:2%3C632::aid-cncr2820740215%3E3.0.co;2-t
24. Nam GE, Baek S-J, Choi HB, Han K, Kwak J-M, Kim J, Kim S-H (2020) Association between abdominal obesity and incident

colorectal cancer: a nationwide cohort study in Korea. Cancers 12:1368. https://doi.org/10.3390/cancers12061368
25. Jayedi A, Soltani S, Zargar MS, Khan TA, Shab-Bidar S (2020) Central fatness and risk of all cause mortality: systematic review and dose-response meta-analysis of 72 prospective cohort studies. BMJ 370:m3324. https://doi.org/10.1136/bmj.m3324
26. Finelli C, Sommella L, Gioia S, La Sala N, Tarantino G (2013) Should visceral fat be reduced to increase longevity? Ageing Res Rev 12:996–1004. https://doi.org/10.1016/j.arr.2013.05.007
27. Moon HU, Lee N, Chung Y-S, Choi YJ (2020) Reduction of visceral fat could be related to the improvement of TBS in diabetes mellitus. J Bone Miner Metab 38:702–709. https://doi.org/10.1007/s00774-020-01107-z
28. Thomsen RS, Nilsen TIL, Haugeberg G, Bye A, Kavanaugh A, Hoff M (2018) Effect of high-intensity interval training on cardiovascular disease risk factors and body composition in psoriatic arthritis: a randomised controlled trial. RMD Open 4:e000729. https://doi.org/10.1136/rmdopen-2018-000729
29. Åsvold BO, Langhammer A, Rehn TA et al (2022) Cohort profile update: the HUNT study, Norway. Int J Epidemiol 52:e80–e91. https://doi.org/10.1093/ije/dyac095
30. Taylor W, Gladman D, Helliwell P, Marchesoni A, Mease P, Mielants H (2006) Classification criteria for psoriatic arthritis: development of new criteria from a large international study. Arthritis Rheumatol 54:2665–2673. https://doi.org/10.1002/art.21972
31. Nes BM, Janszky I, Vatten LJ, Nilsen TI, Aspenes ST, Wisløff U (2011) Estimating V·O 2peak from a nonexercise prediction model: the HUNT Study, Norway. Med Sci Sports Exerc 43:2024–2030. https://doi.org/10.1249/mss.0b013e31821d3f6f
32. Haskell WL, Lee IM, Pate RR et al (2007) Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 39:1423–1434. https://doi.org/10.1249/mss.0b013e3180616b27
33. Balci A, Balci DD, Yonden Z et al (2010) Increased amount of visceral fat in patients with psoriasis contributes to metabolic syndrome. Dermatol 220:32–37. https://doi.org/10.1159/000254482
34. Ferguson LD, Linge J, Leinhard OD et al (2021) Psoriatic arthritis is associated with adverse body composition predictive of greater coronary heart disease and type 2 diabetes propensity—a cross-sectional study. Rheumatology (Oxford) 60:1858–1862. https://doi.org/10.1093/rheumatology/keaa604
35. Leite BF, Morimoto MA, Gomes C et al (2020) Higher bodily adiposity, fat intake, and cholesterol serum levels are associated with higher disease activity in psoriatic arthritis patients: is there a link among fat and skin and joint involvement? Lipids Health Dis 19:21. https://doi.org/10.1186/s12944-020-1200-7
36. Renzo LD, Saraceno R, Schipani C et al (2011) Prospective assessment of body weight and body composition changes in patients with psoriasis receiving anti-TNF-α treatment. Dermatol Ther 24:446–451. https://doi.org/10.1111/j.1529-8019.2011.01439.x
37. Toussirot E, Aubin F, Desmarets M et al (2021) Visceral adiposity in patients with psoriatic arthritis and psoriasis alone and its relationship with metabolic and cardiovascular risk. Rheumatology (Oxford) 60:2816–2825. https://doi.org/10.1093/rheumatology/keaa720
38. Briot K, Garnero P, Le Henanff A, Dougados M, Roux C (2005) Body weight, body composition, and bone turnover changes in patients with spondyloarthropathy receiving anti-tumour necrosis factor α treatment. Ann Rheum Dis 64:1137–1140. https://doi.org/10.1136/ard.2004.028670
39. Pedreira PG, Pinheiro MM, Szejnfeld VL (2011) Bone mineral density and body composition in postmenopausal women with psoriasis and psoriatic arthritis. Arthritis Res Ther 13:R16. https://doi.org/10.1186/ar3240
40. Demirel R, Genc A, Ucok K et al (2013) Do patients with mild to moderate psoriasis really have a sedentary lifestyle? Int J Dermatol 52:1129–1134. https://doi.org/10.1111/ijd.12042
41. Larkin L, Gallagher S, Fraser AD, Kennedy N (2016) Relationship between self-efficacy, beliefs, and physical activity in inflammatory arthritis. Hong Kong Physiother J 34:33–40. https://doi.org/10.1016/j.hkpj.2015.10.001
42. Florin V, Cottencin AC, Delaporte E, Staumont-Sallé D (2013) Body weight increment in patients treated with infliximab for plaque psoriasis. J Eur Acad Dermatol Venereol 27:e186-190. https://doi.org/10.1111/j.1468-3083.2012.04571.x
43. Saraceno R, Schipani C, Mazzotta A, Esposito M, Di Renzo L, De Lorenzo A, Chimenti S (2008) Effect of anti-tumor necrosis factor-α therapies on body mass index in patients with psoriasis. Pharmacol Res 57:290–295. https://doi.org/10.1016/j.phrs.2008.02.006
44. Haglund E, Bergman S, Petersson IF, Jacobsson LT, Strömbeck B, Bremander A (2012) Differences in physical activity patterns in patients with spondylarthritis. Arthritis Care Res (Hoboken) 64:1886–1894. https://doi.org/10.1002/acr.21780
45. Nimmo M, Leggate M, Viana J, King J (2013) The effect of physical activity on mediators of inflammation. Diabetes Obes Metab 15:51–60. https://doi.org/10.1111/dom.12156
46. Wannamethee SG, Shaper AG (2001) Physical activity in the prevention of cardiovascular disease. Sports Med 31:101–114. https://doi.org/10.2165/00007256-200131020-00003
47. Gralla MH, McDonald SM, Breneman C, Beets MW, Moore JB (2016) Associations of objectively measured vigorous physical activity with body composition, cardiorespiratory fitness, and cardiometabolic health in youth: a review. Am J Lifestyle Med 13:61–97. https://doi.org/10.1177/1559827615624417
48. Price KL, Earthman CP (2019) Update on body composition tools in clinical settings: computed tomography, ultrasound, and bioimpedance applications for assessment and monitoring. Eur J Clin Nutr 73:187–193. https://doi.org/10.1038/s41430-018-0360-2
49. Sun G, French CR, Martin GR et al (2005) Comparison of multifrequency bioelectrical impedance analysis with dual-energy X-ray absorptiometry for assessment of percentage body fat in a large, healthy population. Am J Clin Nutr 81:74–78. https://doi.org/10.1093/ajcn/81.1.74