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RESEARCH PAPER

Longitudinal associations between changes in muscle strength, muscle mass, and physical performance and health-related quality of life in older adults: a four-year analysis from the SarcoPhAge cohort

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Key summary points

Aim To investigate the longitudinal associations between changes in sarcopenia components and changes in health-related quality of life, as measured by the SarQoL questionnaire, in older adults.

Findings Despite an overall age-related decline over time, improvements in physical performance, grip strength and muscle mass were independently associated with higher global SarQoL scores.

Message Longitudinal changes in sarcopenia components are associated with changes in HRQoL over time, supporting the importance of monitoring these components in older adults and the use of a sarcopenia-specific questionnaire such as SarQoL.

Abstract

Background Sarcopenia, defined by a decline in muscle strength, muscle mass and physical performance, is associated with poorer health-related quality of life (HRQoL) in older adults. However, longitudinal studies investigating this relationship using sarcopenia-specific HRQoL instruments remain scarce.

Objective To investigate the association between changes in sarcopenia components and changes in HRQoL over four years using the SarQoL questionnaire, a tool specifically designed for individuals with sarcopenia.

Methods This study included 333 community-dwelling older adults from the SarcoPhAge cohort, followed annually for four years. HRQoL was evaluated using the SarQoL questionnaire. Sarcopenia components were measured using a handgrip dynamometer to assess muscle strength, dual-energy X-ray absorptiometry (DEXA) to assess muscle mass and the Short Physical Performance Battery (SPPB) test to assess physical performance. Associations between changes in sarcopenia components and changes in global and domain-specific SarQoL scores were assessed using linear mixed models, with random effects to account for within-subject variation.

Results 333 community-dwelling older adults were included in this study (age: 72.6 years (68.7–77.5), 58.9% women). Over four years, despite an overall age-related decline in sarcopenia components and HRQoL, the increases in physical

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performance ($\beta = 1.04$; $p < .0001$), grip strength ($\beta = 0.195$; $p = .0001$), and muscle mass ($\beta = 2.47$; $p < .0001$) were independently associated with higher global SarQoL scores. Analyses of the seven SarQoL domains yielded consistent findings.
Conclusion The results support the use of the SarQoL questionnaire as a specific and sensitive instrument for monitoring HRQoL in older adults as it appears responsive to changes in muscle mass, strength, and physical performance.

Keywords Sarcopenia · Health-related quality of life · SarQoL · Physical performance · Muscle strength · Muscle mass

Introduction

Quality of life (QoL) is a multidimensional concept encompassing the individual's perception of their physical health, psychological state, level of independence, social interactions, and the relationship with key environmental factors [1]. Importantly, QoL is increasingly recognized not only as an outcome but also as a key component in assessing the impact of chronic diseases and geriatric conditions on daily functioning and well-being [2]. Health-related quality of life (HRQoL) focuses specifically on the impact of health status on QoL [3]. HRQoL is usually assessed using standardized questionnaires belonging to the broader category of patient-reported outcome measures (PROMs). These questionnaires are increasingly used in clinical research to capture the patients' subjective experiences and complement traditional clinical indicators [4].

Sarcopenia is a common geriatric condition, with an estimated prevalence of between 10 and 27% in the population of older adults aged 60 years and over [5]. While there is no universally accepted definition, sarcopenia is commonly characterized by a decline in three core components: muscle strength, muscle mass, and physical performance [6–10]. In addition to its physiological consequences, including an increased mortality and hospitalization [11], sarcopenia is also associated with a significant decline in quality of life [12, 13]. Historically, HRQoL in people with sarcopenia has been assessed using generic tools such as the 36-item Short Form Health Survey (SF-36) or the Euroqol five item questionnaire (EQ-5D) questionnaires. However, these instruments may lack sensitivity to the specific impairments and limitations associated with sarcopenia. In response to this, the Sarcopenia and Quality of life (SarQoL) questionnaire was developed in 2015 as the first PROM specifically designed to assess HRQoL in sarcopenic populations [14]. This validated, self-administered instrument covers multiple domains, including notably physical and mental health, locomotion, functionality, and activities of daily living, making it particularly suited to explore the subjective burden of sarcopenia.

Despite the availability of cross-sectional data on the relationship between sarcopenia and HRQoL, longitudinal studies remain limited. Furthermore, existing longitudinal studies have only used generic HRQoL instruments and have not disaggregated sarcopenia into its core components. Moreover, the majority of these studies have used sarcopenia status at baseline. However, it has been demonstrated that sarcopenia, and more specifically, its core components, can deteriorate or improve over time [15–17]. The present study aims to address these gaps by investigating whether longitudinal changes in muscle mass, muscle strength, and physical performance are associated with longitudinal changes in HRQoL as measured by a specific-instrument, namely the SarQoL questionnaire, over a four-year period in community-dwelling older adults from the SarcoPhAge cohort.

Methods

Population

This study used data from the SarcoPhAge (Sarcopenia and Physical Impairment with Advancing Age), a prospective observational study initiated in 2013. The cohort initially included 534 community-dwelling participants aged 65 years or over, who were followed for five years. Participants were recruited in Liège (Belgium) and were eligible if they lived in the community, were able to walk independently, and agreed to attend annual follow-up visits. The study design of this cohort has been described in detail elsewhere [18].

The present study used data from five annual follow-up waves (Y1 to Y5). As the SarQoL questionnaire was introduced at Y1, information collected at Y0 was excluded from the analysis. Only participants who completed the SarQoL questionnaire at Y1, defined as the baseline for this study, were considered eligible (n = 387, 72.5%). Given the aim to analyze the longitudinal evolution of SarQoL scores, participants with fewer than two visits involving a SarQoL assessment were excluded. This resulted in a final sample size of 333 participants (62.3%) for the longitudinal analysis (Fig. 1).

Ethics Statement

This study has been approved by the Ethics Committee of the Teaching Hospital of the University of Liège (reference

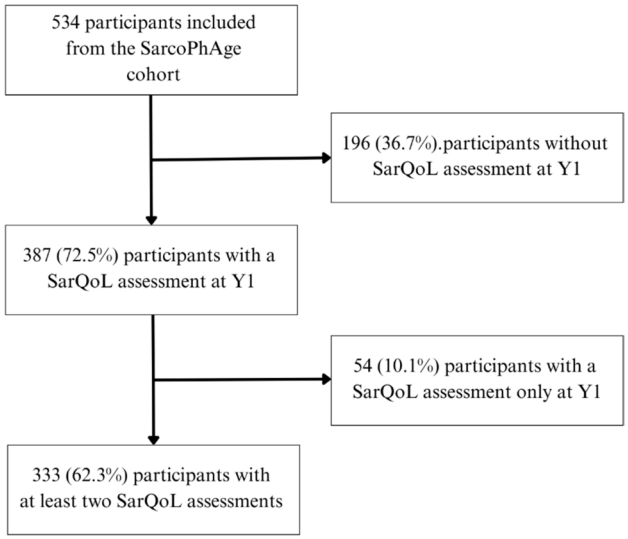

Fig. 1 Selection of participants included in the analysis

2012/277). Written informed consent was obtained from all participants before they were included in the study.

Health-related quality of life

HRQoL was assessed using the SarQoL questionnaire. This validated self-administered questionnaire is specifically designed to measure HRQoL in people with sarcopenia. The questionnaire consists of 22 questions comprising 55 items distributed across seven different domains: physical and mental health, locomotion, body composition, functionality, activities of daily living, leisure activities, and fears. Each domain is scored from 0 to 100 and these scores are then converted into a global score, also ranging from 0 to 100 with higher scores indicating higher levels of HRQoL. The SarQoL has demonstrated good psychometric properties, content validity and responsiveness [19–21].

Components of sarcopenia

Sarcopenia was assessed according to the criteria proposed by the EGWSOP definition, with each component considered separately in this study [7].

- Muscle strength was measured using a hydraulic hand dynamometer (Saehan Corporation, Korea or MSD Europe Bvba, Belgium). Participants pressed the dynamometer three times with each hand, and the highest value was taken as the reference [22].
- Muscle mass, operationally assessed as appendicular lean mass, was measured using dual-energy X-ray absorptiometry (DEXA; Hologic Discovery A, USA), with daily calibration to ensure accuracy. Skeletal muscle mass index (SMI) was calculated by dividing appendicular lean mass by height squared (kg/m^2).
- Physical performance was assessed using the Short Physical Performance Battery (SPPB) test, which includes a balance test, a walking speed test and a chair-stand test [23].

Covariates

In addition to the HRQoL and sarcopenia components, additional data were systematically collected from all participants at each annual follow-up visit. Some of these were considered potential confounders due to their reported association with QoL and sarcopenia and were therefore included in our statistical models. The following covariates were therefore included: age, gender, level of education, number of concomitant diseases, number of medications, nutritional status assessed by the Mini Nutritional Assessment (MNA) [24], limitation in activities and functional activities of daily living assessed by the Katz and Lawton scales [25, 26], cognitive function evaluated using the validated French version of the Mini Mental State Examination (MMSE)[27], depressive symptoms assessed by the validated French version of the Geriatric Depression Scale (GDS) [28], and level of activity measured using the validated French version of the Minnesota scale [29].

Statistical analysis

Qualitative variables were summarized using frequency tables, while quantitative variables were expressed as median and interquartile range (Q1–Q3). The normality of the distribution was assessed using histograms, Q–Q plots and Shapiro–Wilk test. Given the well-established sex-related differences in muscle strength, muscle mass, and physical performance, baseline values for sarcopenia components were reported separately for men and women.

All the variables were considered longitudinally (i.e., changes between the different follow-up times), except for age, gender and education, which were only considered at baseline. Linear mixed effects models for longitudinal data were used to examine factors associated with HRQoL in participants. A random effect was included in each model to account for within-subject variation due to repeated individual measurements over time. The model was adjusted for baseline characteristics and identified potential confounders. To account for the difference in Lawton score between men and women, the interaction between gender and Lawton score was included in the model. Model results are reported as coefficients (β), standard errors (SE) and p values. As certain variables (i.e., MMSE, MNA and GDS) were not available at the third visit (Y3), the data corresponding to this wave were not included in the model. The same approach

was followed for each of the seven SarQoL domains. Model results are reported as coefficients (β), standard errors (SE), 95% confidence intervals (95%CI) and p values, reflecting the estimated fixed effect from the linear models. These coefficients quantify the association between each independent variable, adjusted for random effects and other covariates.

All available observations were included in the analysis with no imputation of missing data, and handgrip measurements that could not be obtained were coded as missing and handled directly by the mixed effects models. Confidence level was set at 95% ($p < 0.05$), statistical analysis was performed using R (version 4.2.0), and linear mixed models were conducted using nlme R package [30].

Results

Table 1 presents the baseline characteristics of the 333 participants included in this study from the SarcoPhAge cohort. The median age of the participants was 72.6 years (68.7–77.5) and 196 participants (58.9%) were women. The majority had a high level of education (40.2%). The median number of follow-up visits was 4 (3–5). The median body mass index was 26.8 kg/m^2 (23.8–30.0) and the MMSE was 29 (28–30). The median Katz scale score was 8 (8–8) while the median score for instrumental activities of daily living, assessed using the Lawton scale, was 5 (5–5) for men and 8(8–8) for women. The median energy expenditure, measured with the Minnesota questionnaire, was 897 kcal/day (368–1580). The median GDS score was 2 (1–5). The median number of concomitant diseases was 4 (3–5) and the median number of medications per day was 5 (3–8). According to the EWGSOP2 criteria, 12 participants (3.6%) were identified as sarcopenic.

Table 1 Baseline characteristic of the participants ($n = 333$)

	Total ($n = 333$)
Age, years	72.6 [68.7–77.5]
Gender	
Women	196 (58.9%)
Level of education	
Without qualification	5 (1.5%)
Primary school	29 (8.7%)
Lower secondary school	62 (18.6%)
Upper Secondary school	99 (29.7%)
Post-secondary education	134 (40.2%)
Doctoral	4 (1.2%)
Follow-up, number	4.00 [3.00–5.00]
BMI, kg/m^2	26.8 [23.8–30.0]
MMSE,/30 points	29.0 [28.0–30.0]
Katz,/24 points	8.00 [8.00–8.00]
Minnesota, kcal/day	897 [368–1580]
GDS,/15 points	2.00 [1.00–5.00]
Concomitant disease, number	4.00 [3.00–5.00]
Medication, number per day	5.00 [3.00–8.00]
Lawton	
Men,/5points	5.00 [5.00–5.00]
Women,/8points	8.00 [8.00–8.00]

BMI Body Mass Index, *MMSE* Mini Mental State Examination, *GDS* Geriatric Depression Scale

Baseline values for sarcopenia components are presented in Table 2. The median SPPB score was 11.0 [9.0–12.0] in both men and women. Median grip strength was 39.5 kg [35.0–45.0] in men and 21.0 kg [18.0–25.0] in women. Median SMI was 7.77 kg/m^2 [7.17–8.55] in men and 6.05 kg/m^2 [5.45–6.67] in women.

The longitudinal evolution of the sarcopenia components is detailed in Table S1. The investigation revealed that SPPB scores demonstrated consistent stability across the five assessments, with median values ranging from 10.0 to 11.0. Conversely, median grip strength exhibited a more pronounced decline over time, decreasing from 26.0 kg at baseline to 20.0 kg at T5, while SMI values demonstrated a more moderate yet consistent downward trend. Supplementary Table S2 presents the evolution of HRQoL. The global SarQoL score showed a gradual decrease over the follow-up period, with similar trajectories observed across most of its dimensions.

Although overall levels of physical performance, muscle strength, muscle mass, and HRQoL decreased over the follow-up period (Tables S1 and S2), subsequent analyses examined how changes in sarcopenia components were associated with changes in HRQoL over time. Results from the adjusted linear mixed effects regression assessing the association between changes in sarcopenia components and changes in the global SarQoL score are shown in Table 2. In this table, positive coefficients indicate that an increase in the corresponding sarcopenia component (grip strength, SMI, or SPPB score) is associated with an increase in the corresponding SarQoL domain score. Over the 4-year follow-up period, significant and independent associations between increases in HRQoL and sarcopenia components were observed. More specifically,

Table 2 Baseline sarcopenia components by gender

	Men ($n = 137$)	Women ($n = 196$)
Sarcopenia component		
SPPB,/12 points	11.0 [9.00–12.0]	10.0 [9.00–12.0]
Grip strength, kg	39.5 [35.0–45.0]	21.0 [18.0–25.0]
SMI, kg/m^2	7.77 [7.17–8.55]	6.05 [5.45–6.67]

SPPB Short Physical Performance Battery, *SMI* Skeletal muscle mass index

improvements in physical performance, as measured by changes in SPPB scores over time, were significantly associated with increases in the global SarQoL score ($\beta = 1.04$, $p < 0.0001$). Similarly, improvements in grip strength ($\beta = 0.195$, $p = 0.0001$) and skeletal muscle mass index ($\beta = 2.47$, $p < 0.0001$) were independently associated with an increase of HRQoL.

As presented in Table 3, after adjustment for potential confounders, improvements in physical performance were significantly associated with increased HRQoL across all seven SarQoL domains (all $p < 0.01$). Improvements in grip strength were also associated with increased HRQoL scores in domain 1 (physical and mental health), domain 4 (functionality), and domain 5 (leisure activities). Finally, increased scores in SMI were significantly associated with higher HRQoL scores in five of the seven SarQoL domains. Although the associations between SMI and domains 6 (fears) and 7 (mobility), as well as between grip strength and domains 2, 3, 6, and 7, did not reach statistical significance, the observed trends remained consistent with those of the global SarQoL scores (Table 4).

Discussion

In the present study, we have investigated the association between longitudinal changes in muscle mass, muscle strength, and physical performance with the longitudinal changes of HRQoL over a 4-year follow-up period. To our knowledge, this is the first study to explore the three components of sarcopenia in relation to HRQoL, assessed using SarQoL, the only questionnaire specifically designed for individuals with sarcopenia. This study highlighted that, in a context of overall age-related decline in both sarcopenia components and HRQoL, increases in muscle mass, muscle strength, and physical performance were independently and significantly associated with a higher HRQoL level. These findings should be interpreted in light of the global trajectories observed in our sample. As shown in the supplementary material, both sarcopenia components and HRQoL tended to decline progressively over time, which is consistent with expected age-related changes. However, our analytical approach focused on variations within individuals around these general trends. From this perspective, presenting the results positively was a deliberate interpretative choice: even within an overall context of decline, older

Table 3 Results of the adjusted linear mixed model modeling changes in the global SarQoL score in association with changes with sarcopenia components ($n = 333$)

		Coefficient ± SE	95%CI	*p* value
Follow-up, days		− 0.002 ± 0.0005	− 0.003, − 0.001	***< 0.0001***
Sarcopenia components				
SPPB		1.04 ± 0.170	0.708, 1.37	***< 0.0001***
Grip strength, kg		0.195 ± 0.050	0.097, 0.293	***0.0001***
SMI, kg/m^2		2.47 ± 0.596	1.30, 3.64	***< 0.0001***
Gender (ref = men)	Women	1.75 ± 4.46	− 7.02, 10.52	0.69
Age, years		− 0.351 ± 0.096	− 0.539, 0.163	***0.0003***
Education (ref = none)	Primary school	− 0.368 ± 4.68	− 9.57, 8.83	0.94
	Lower secondary school	0.994 ± 4.50	− 7.85, 9.84	0.83
	Upper secondary school	1.83 ± 4.44	− 6.90, 10.6	0.68
	Post-secondary education	2.31 ± 4.42	− 6.39, 11.0	0.60
	Doctoral	2.33 ± 6.34	− 10.1, 14.8	0.71
BMI, kg/m^2		− 0.845 ± 0.134	− 1.11, − 0.582	***< 0.0001***
MMSE,/30 points		− 0.010 ± 0.135	− 0.275, 0.254	0.94
Katz scale,/24 points		− 0.482 ± 0.218	− 0.910, −0.054	*0.027*
Lawton (ref = men)	Women	0.115 ± 0.770	− 0.816, 1.92	0.88
MNA,/12 points		0.364 ± 0.179	− 1.40, 1.63	*0.043*
Minnesota, kcal/week		0.0003 ± 0.0001	0.012, 0.717	***0.0022***
GDS,/15points		− 1.10 ± 0.099	0.0001, 0.0006	***< 0.0001***
Concomitant disease, number		− 0.771 ± 0.184	− 1.30, − 0.910	***< 0.0001***
Medication, number		− 0.332 ± 0.094	− 1.13, − 0.411	***0.0004***

SE standard error; Model adjusted for baseline characteristics (age, gender, education) and for changes in BMI, cognitive status, functional status, nutritional status, depressive symptoms, concomitant diseases, and the number of medications − 0.516; − 0.147

Values in bold italics indicate statistically significant results (p 0.05)

Table 4 Results of the adjusted linear mixed models modeling changes in the seven domains of SarQoL with the sarcopenia components changes ($n = 333$)

	Grip strength (kg)			SMI (kg/m^2)			SPPB		
	Coefficient ± SE	95%CI	*p* value	Coefficient ± SE	95%CI	*p* value	Coefficient ± SE	95%CI	*p* value
D1 Physical and mental health	0.147 ± 0.07	0.016, 0.279	**0.028**	2.16 ± 0.78	0.638, 3.69	**0.0055**	0.982 ± 0.23	0.525, 1.44	**< 0.0001**
D2 Locomotion	0.123 ± 0.08	− 0.042, 0.287	0.14	3.60 ± 0.99	1.67, 5.54	**0.0003**	1.39 ± 0.29	0.811, 1.97	**< 0.0001**
D3 Body Composition	0.103 ± 0.08	− 0.049, 0.255	0.18	1.94 ± 0.89	0.181, 3.70	**0.031**	0.986 ± 0.28	0.439, 1.53	**0.0004**
D4 Functionality	0.171 ± 0.06	0.061, 0.282	**0.0024**	2.46 ± 0.66	1.16, 3.76	**0.0002**	1.43 ± 0.19	1.05, 1.81	**< 0.0001**
D5 Activities of daily living	0.341 ± 0.07	0.196, 0.486	**< 0.0001**	2.86 ± 0.87	1.15, 4.57	**0.0011**	1.09 ± 0.26	0.579, 1.60	**< 0.0001**
D6 Leisure activities	0.102 ± 0.10	−0.090, 0.294	0.30	1.65 ± 1.10	− 0.520, 3.81	0.14	1.75 ± 0.37	1.03, 2.47	**< 0.0001**
D7 Fears	0.045 ± 0.06	− 0.073, 0.162	0.45	1.62 ± 0.68	0.295, 2.95	**0.017**	0.579 ± 0.22	0.148, 1.01	**0.0086**

Models adjusted for baseline characteristics (age, gender and level of education) and for longitudinal changes in follow-up time, body mass index, level of cognition, activities of daily living, instrumental activities of daily living, level of activity, nutritional status, depressional symptoms, number of concomitant diseases and medications

SE Standard error, *95%CI* 95% confidence interval, *Kg* kilograms, *SMI* Skeletal Muscle Mass Index, m^2 meter squared, *SPPB* Short Physical Performance Battery, *SE* standard error

Values in bold italics indicate statistically significant results (p 0.05)

adults who improved their physical capacity reported an improvement in their HRQoL over time. This suggests that variations in physical capacity may offer opportunities to help preserve HRQoL even within an overall context of age-related decline, although caution remains warranted when interpreting these associations.

To our knowledge, the only other longitudinal study, using the same statistical analysis as ours, that explored the relationship between HRQoL and sarcopenia components is the study by Trombetti et al. [31]. Our findings partially align with those reported in their study. First, contrary to the study by Trombetti et al., a significant association between muscle strength and HRQoL was observed in the present study. This difference could be partially explained by the different methods used to assess muscle strength. Indeed, Trombetti et al. used the lower extremity muscle strength, whereas we used grip strength. Furthermore, they assessed HRQoL using the SF-36 questionnaire in a relatively small sample size ($N = 48$), whereas this generic questionnaire has been reported to be less sensitive than SarQoL in measuring HRQoL [12]. On the other hand, and consistently with our findings, they also reported a significative association between muscle mass and HRQoL ($\beta = 0.102$, $p = 0.046$). However, it should be noted that different methods were used to assess muscle mass. Indeed, Trombetti et al. measured muscle mass using computed tomography while DEXA was used in the present study. Finally, the present study showed an association between physical performance and HRQoL. which is in line with Trombetti et al., who demonstrated that increased SPPB scores were associated with a higher HRQoL level over 3 years. These findings are reinforced by a large longitudinal study which, although not directly evaluating the HRQoL, showed a significant association between SPPB scores and mobility impairment, ADL disabilities and IADL disabilities over a period of 12 years [32]. Interestingly, these aspects (i.e., mobility and (I)ADL) are covered by various domains of the SarQoL questionnaire. This conceptual overlap reinforces the robustness of the observed association between physical performance and HRQoL.

One of the key strengths of this study is that it is, to our knowledge, the first study to investigate the association between changes in sarcopenia components and HRQoL assessed using the SarQoL instrument. To date, SarQoL is the only sarcopenia-specific questionnaire and offers a more appropriate alternative than generic questionnaires for assessing HRQoL regarding the sarcopenia components in older populations [12]. Additionally, the data regarding HRQoL and sarcopenia components were treated longitudinally as were all the variables that were introduced in the model (except for age, gender, and level of education). This allowed for the capture of intra-individual changes in sarcopenia components and their association with HRQoL over

a period of 4 years, independently of the evolution of other covariates. Another strength lies in the consistency of the observed associations across the seven SarQoL domains. While muscle strength and mass were associated with most of the domains, physical performance was consistently associated with all of them. This multidimensional consistency strengthens the robustness of our findings and underscores the value of domain-specific assessments in capturing the more nuanced aspects of HRQoL. Interestingly, even without applying a threshold-based definition to each sarcopenia component, SarQoL scores appeared sensitive to changes in muscle mass, strength and physical performance. This suggests that SarQoL may capture relevant variations in HRQoL and have a broader utility in older adults experiencing physical decline, beyond those formally diagnosed with sarcopenia. This important finding suggests that SarQoL may have broader utility in clinical practice and research, particularly in the context of prevention and intervention.

Nevertheless, some limitations must be acknowledged. First, this research was carried out exclusively in Belgium. However, it has been reported that quality of life measures may vary in different cultural or geographical contexts [33]. This could potentially limit the external validity and generalization of our findings. Therefore, caution should be exercised when extrapolating our findings to populations with different sociocultural contexts. In addition, some potential confounding factors that have been reported as being associated with HRQoL in relation to muscle strength, muscle mass, and physical performance, such as nutritional intake, lifestyle habits, and sleep quality [34–36], were not included in this study as the necessary data were not collected during the SarcoPhAge cohort follow-up. Another potential limitation is the lack of information on any medical or lifestyle interventions that participants may have received during the follow-up period. Indeed, treatments or interventions such as physiotherapy or nutritional support may have affected muscle strength, muscle mass and physical performance, and consequently quality of life [37, 38]. Finally, due to the absence of certain covariates at Y3, this wave could not be included in the adjusted mixed effects models. Although mixed models facilitate the utilization of all available observations and are well-suited to the management of missing longitudinal data, the exclusion of this assessment, as well as losses to follow-up due to death, may have reduced the amount of available information and introduced a non-random loss of data, which should be acknowledged as a potential source of bias.

In conclusion, this study highlights that increases in muscle mass, muscle strength, and physical performance were each associated with higher HRQoL over time, after adjustment for all covariates and for the other sarcopenia components included in the model. These findings emphasize the importance of regularly monitoring sarcopenia components in older adults to maintain or improve their quality of life. Using a sarcopenia-specific questionnaire, such as SarQoL, appears to be an appropriate and informative approach in this context. Further longitudinal studies using the SarQoL questionnaire are needed to confirm these results in other populations and settings.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s41999-026-01415-z.

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Declarations

Conflict of interest C.B., J-Y.R., and O.B. are stakeholders of SARQOL SRL, a spin-off of the University of Liège in charge of the interests of SarQoL. However, they did not receive any financial compensation for this role.

Ethical approval This study has been approved by the Ethics Committee of the Teaching Hospital of the University of Liège (reference 2012/277).

Informed consent Written informed consent was obtained from all participants before they were included in the study

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