Anthropometric trajectory in the course of life and occurrence of sarcopenia in men and women: results from the ELSA-Brasil cohort

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Abstract

This study aimed to identify patterns of anthropometric trajectories throughout life and to analyse their association with the occurrence of sarcopenia in people from the Longitudinal Study of Adult Health (ELSA-Brasil). It is a cross-sectional study involving 9670 public servants, aged 38–79 years, who answered the call for new data collection and exams, conducted approximately 4 years after the study baseline (2012–2014). Data sequence analysis was used to identify patterns of anthropometric trajectory. A theoretical model was elaborated based on the directed acyclic graph (DAG) to select the variables of minimum adjustment in the analysis of the causal effect between trajectory and sarcopenia. Poisson regression with robust variance was adopted for data analysis. The patterns of change in the anthropometric trajectory were classified in stable weight (T1); change to normal weight (T2); change to excess weight (T3); weight fluctuation (T4) and change to low weight (T5). The prevalence of sarcopenia in men and women who changed the anthropometric path for the low weight was twice as large when compared to participants with a stable weight trajectory. A protective effect of the excess weight trajectory was observed for the occurrence of sarcopenia in them. The results pointed to the need for health policies that encourage the proper management of body components in order to prevent and control obesity, as well as to preserve the quantity and quality of skeletal muscle mass throughout life, especially in older adults.

Key words: Sarcopenia: Ageing: Chronic diseases: BMI

Sarcopenia is characterised by a decline in skeletal muscle mass, strength and physical function[1] and affects about 10 % of adults over 60 years and 50 % of older adults over 80 years old worldwide[2]. Adverse changes related to the development and maintenance of skeletal muscle (e.g. denervation and adaptations in motor units of type I and II muscle fibres, mitochondrial dysfunction and inflammatory, hormonal and nutritional changes) may accumulate throughout life, explaining the occurrence and progression of sarcopenia in older adults[1].

Although related to ageing, sarcopenia may also occur early[3,4] due to ageing progression, sedentary lifestyle, inadequate nutrition and chronic, inflammatory, rheumatologic and neurological conditions[1]. Sarcopenia is considered an important predictor of mortality among older adults[5] and may also lead to decreased bone mineral density, functional disability, increased probability of falls, respiratory problems[6–10] and increased healthcare costs[11]. Despite its recent recognition as a muscle disease by the International Disease Code (ICD-10-CM (M62.84))[12], the underlying aetiology of sarcopenia remains unknown. Underlying factors (e.g. changes in the anthropometric trajectory) occur at all life stages, especially in countries where the nutritional pattern and accelerated population ageing are relevant, such as Brazil.

Abbreviations: DAG, directed acyclic graph; PR, prevalence ratio.

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The anthropometric trajectory is the general pattern of body weight changes (i.e. transition from one state of body weight to another) that occurs throughout life. This pattern may represent an important marker of body change and includes the investigation of composition, risk of chronic non-communicable diseases and mortality in adults[13–15]. The anthropometric trajectory is even worrisome when low birth weight is present, which may be related to decreased skeletal muscle mass, slow muscle development[16–18], decreased muscle strength[19,20] and increased percentage of body fat[21–24] in the subsequent years of life.

Evidence indicates positive associations between excessive body weight and progression of sarcopenia[13,25], prevalence of cardiometabolic diseases and conditions[26,27] and increased risk of mortality[28] in adults. However, low body weight is considered a risk factor for sarcopenia, especially in older adults[29,30].

Additionally, stable weight and maintenance of the ideal anthropometric status throughout life are strategies adopted by health promotion and prevention policies related to non-communicable and chronic diseases[31–33]. Despite the evidence, literature lacks studies about the role of patterns of change in anthropometric trajectories throughout life (from birth to adulthood) and their influence on sarcopenia in adults.

Therefore, to overcome this gap and provide evidence for preventing the occurrence and progression of sarcopenia in adults, this study aimed to identify the anthropometric trajectories throughout life and analyse their association with the prevalence of sarcopenia. We hypothesised that patterns of anthropometric trajectories that initiated with low birth weight and changes to low weight are associated with the occurrence of sarcopenia in men and women from the Longitudinal Study of Adult Health (ELSA-Brasil) cohort.

Methods

Study design

This cross-sectional study used data from the largest observational and multicentre cohort in Latin America (ELSA-Brasil), which prospectively investigated diseases, chronic conditions and risk factors of 15 105 participants since 2008. A total of 1091 (7·2 %) participants did not answer the second call of the study (wave 2 from 2012 to 2014), and the loss to follow-up due to death comprised 223 (1·48 %) participants.

A sample of 14 014 civil servants aged between 38 and 79 years from three Brazilian regions (Northeast, Southeast and South) who answered the call to return to the investigation centres was considered for new data collection and exams (2012–2014) 4 years after the study baseline. Data were collected from the second wave of the ELSA-Brasil by a previously trained team of researchers using standardised instruments and procedures. The detailed study design and procedures are available in the literature[34–37].

Exclusion criteria were participants with no information about birth weight, weight at 20 years old and weight and height at baseline and after 4 years of follow-up. We also excluded participants without information about electrical bioimpedance analysis and handgrip strength from the second wave of the study; absence of limbs; use of metallic prostheses; changes in protocols for anthropometric (weight and height), bioimpedance analysis and handgrip strength measurements; bariatric surgery or those self-declared yellow or indigenous. After applying the eligibility criteria, we selected 9670 participants (Fig. 1).

Ethical criteria

The study was approved by the ELSA-Brasil committee, the National Research Ethics Commission (CONEP No. 13065) and the research ethics committee of six affiliated centres: Oswaldo Cruz Foundation, Federal University of Bahia, Federal University of Minas Gerais, University of São Paulo, Federal University of Espírito Santo and Federal University of Rio Grande do Sul. The study protocol met all ethical requirements from the National Health Council (nº 196/96) for research involving humans. All participants signed the informed consent form[35].

Definition of the anthropometric trajectory (independent variable)

To examine the anthropometric trajectory of each participant, we gathered self-reported information about birth weight and weight at 20 years old (baseline) and anthropometric data (weight and height at baseline and 4 years after the follow-up) from the ELSA-Brasil.

Self-reported birth weight at baseline was categorised as low (< 2·5 kg), normal (between 2·5 kg and 4 kg) or overweight (≥ 4 kg) and used as an indicator of nutritional status and body mass in this period of life[24].

BMI at 20 years old was calculated using the Quételet index (body weight in kg divided by height squared in meters (kg/m^2)) according to self-reported weight and height. We used the weight and height obtained from the ELSA-Brasil to estimate BMI at baseline (2008–2010) and after 4 years of follow-up (2012–2014). The following cut-off points recommended by the World Health Organization[38] were adopted for BMI and considered for the trajectory analysis: low (BMI < 18·5), normal (BMI ≥ 18·5 and ≤ 24·9) and overweight (BMI ≥ 25).

Birth weight and BMI were also used to represent the anthropometric states according to three elements or categories of responses. The elements presented a uniform pattern in the four time points assessed (P) (low, normal and overweight). The variable patterns of anthropometric trajectory were developed to understand the different patterns of weight change throughout life according to the sequence of anthropometric states: birth weight (P1), transition at 20 years old (P2), baseline (P3) and approximately 4 years after the beginning of follow-up (P4).

Subsequently, four states were considered over time, with three corresponding elements in each state. Based on the number of states and evaluated elements, eighty-one possible patterns of combinations were estimated, and fifty-four different patterns of trajectory were identified. These patterns were regrouped into categories of trajectories that shared similar elements between the initial and final transition states. Based on the criteria for regrouping, five categories of anthropometric trajectories throughout life were defined: one characterised by a
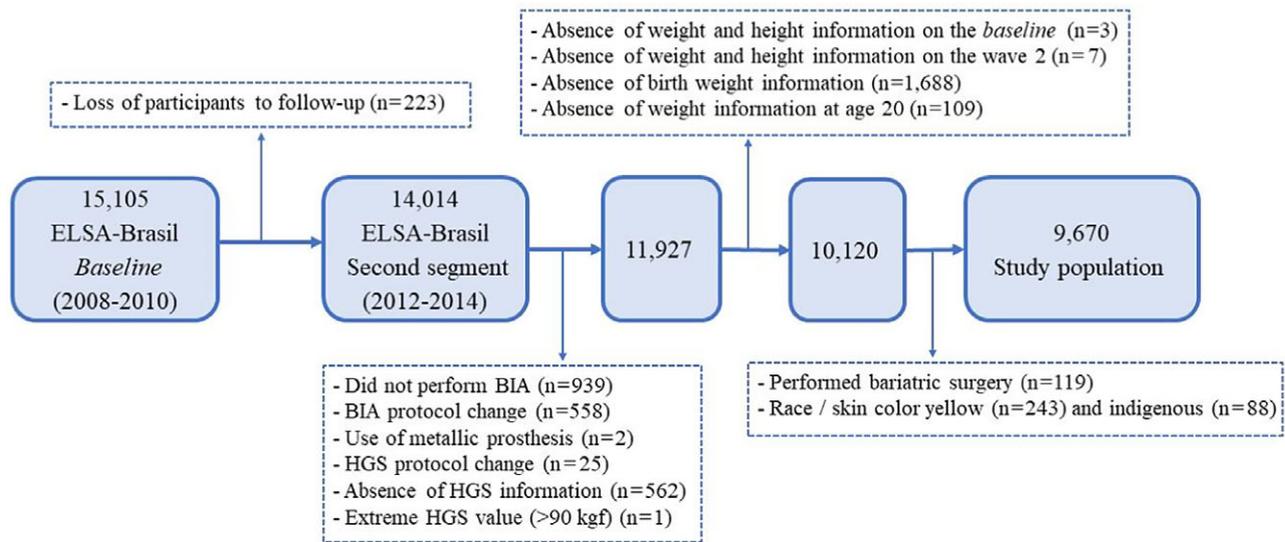
Fig. 1. Flow chart of selection of the study population. BIA, bioimpedance analysis; HGS, handgrip strength.

pattern of stable weight (i.e. without variation in the classification of body weight throughout life) (T1) and four characterised by different patterns of change in body weight. The latter included changes to normal weight, starting with low weight or overweight at birth and ending with normal weight (T2); changes to overweight, starting with low or normal weight and ending with overweight (T3); weight fluctuation, with a maintenance pattern throughout data collection periods and fluctuation during the trajectory (T4) and changes to low weight, starting with overweight at birth and ending with low weight (T5) (Table 1).

Definition of sarcopenia (dependent variable)

Sarcopenia was defined following the recommendations of the European Diagnostic Consensus for Sarcopenia in the Elderly and the International Working Group on Sarcopenia[1,39]. In our study, cut-off points for reduced muscle strength and mass were estimated based on data from the ELSA-Brasil. We used specific cut-off points to categorise skeletal muscle mass decline based on data from young adults due to lack of criteria for defining and diagnosing sarcopenia in Latin American populations. Moreover, a subsample of younger adults (< 45 years) without chronic disease from the ELSA-Brasil at baseline was used to categorise skeletal muscle mass decline[40,41].

Thus, this study considered sarcopenia if skeletal muscle mass index (skeletal muscle mass/height^2) was reduced and handgrip strength was below the estimated cut-off point according to the age range for men and women in the ELSA-Brasil.

Handgrip strength. Handgrip strength was measured using the Jamar® dynamometer (Sammons Preston) adjusted in a single position for all participants (position three at the top and position two at the bottom at the gauge). Three measurements were performed on each hand, starting with the dominant hand, followed by the non-dominant hand. Participants comfortably sat in a chair with back and forearm support, shoulders slightly abducted, elbow flexed at 90° and thumb facing up. During the test, participants were verbally encouraged to perform as much strength as possible. For data analysis, we considered the best strength performance among measurements in each hand[42].

Values below 42, 41, 38 and 35 kg in men and 26, 23, 23 and 21 kg in women ageing, respectively, 38–44, 45–54, 55–64 and ≥ 65 years indicated low performance.

Skeletal muscle mass. Skeletal muscle mass was measured by bioimpedance analysis (total skeletal muscle mass) using the Inbody 230® Bioimpedance equipment (Biospace Co., Ltd). Reduced skeletal muscle mass was considered if skeletal muscle mass index was lower than one standard deviation from the mean value of the younger adult group (< 45 years), which was skeletal muscle mass index < 10·03 kg for men and < 8·0 kg for women. The use of skeletal muscle mass index to categorise normal muscle mass and sarcopenia was suggested by Janssen *et al.* in a study conducted with data from the Third National Health and Nutrition Examination Survey[41].

All results were assessed according to the Manual of Procedures of Wave 2 for Anthropometry and Bioimpedance and the Manual of Isometric Force Measurement of Hand Grasping/ELSA-Brasil (2012) developed especially for ELSA-Brasil.

Covariates

Covariates were collected during an interview conducted using the ELSA-Brasil questionnaire[36]. Socio-demographic characteristics comprised age, expressed in years and categorised in ranges (38–54 years, 55–64 years and ≥ 65 years); skin colour (white, brown and black); education (elementary or high school, or higher education) and per capita income (family income categorised by tertiles based on the number of residents who depended on this income).

Table 1. Patterns of anthropometric sequences during the life course used to shape the trajectories. Longitudinal Study of Adult Health (ELSA-Brasil) (2008–2010) and (2012–2014)
(Numbers and percentages)

Anthropometric trajectory	Sequence	n	Frequency (%)
T1 – Stable weight	NNNN	1575	16·29
	OOOO	74	0·77
	LLLL	3	0·03
T2 – Change to normal weight	LNNN	153	1·58
	LLNN	72	0·74
	LNON	17	0·18
	LLON	5	0·05
	LLLN	5	0·05
	LNLN	4	0·04
	LONN	4	0·04
	LOLN	1	0·01
	ONNN	111	1·15
	OLNN	33	0·34
	ONON	13	0·13
	OONN	8	0·08
	OLON	7	0·07
	ONLN	1	0·01
	OOON	1	0·01
T3 – Change to overweight	NNOO	3859	39·91
	NOOO	597	6·17
	NLOO	535	5·53
	NNNO	514	5·32
	NLNO	122	1·26
	NONO	28	0·29
	NOLO	1	0·01
	LLOO	76	0·79
	LNOO	320	3·31
	LOOO	59	0·61
	LNNO	46	0·48
	LLNO	18	0·19
	LONO	4	0·04
T4 – Fluctuation of weight	LNLL	1	0·01
	LNNL	1	0·01
	NLNN	592	6·12
	NNON	191	1·98
	NONN	47	0·49
	NLON	32	0·33
	NLLN	14	0·14
	NOON	12	0·12
	NNLN	10	0·10
	ONOO	365	3·77
	ONNO	*39*	*0.40*
	OLOO	37	0·38
	OLNO	6	0·06
	OONO	3	0·03
T5 – Change to low weight	NLLL	23	0·24
	NLNL	6	0·06
	NNNL	10	0·10
	NNLL	8	0·08
	NNOL	1	0·01
	NONL	1	0·01
	OLLL	2	0·02
	ONNL	2	0·02
	ONLL	1	0·01
Total	54	9670	100·00

L, low weight; N, normal; O, overweight.

Leisure-time physical activity (yes or no) was measured according to the International Physical Activity Questionnaire-long form[43]. Participants who practised ≥ 150 min of moderate physical activity or walking or both/week, ≥ 60 min of vigorous physical activity or combined ≥150 min of walking with moderate and vigorous physical activity were considered active at leisure. Leading institutions recommend these cut-off points for promoting and maintaining health[44,45].

Other health-related behaviours were also considered in the analysis, such as excessive alcohol consumption (yes or no), categorised based on alcohol intake (≥ 210 g/week for men and ≥ 140 g/week for women)[46]; smoking (never smoked, ex-smoker or smoker); changes in diet to lose weight in the last 6 months (yes or no); use of vitamin and mineral supplements (yes or no) and short sleep duration, obtained from information on sleep time on a usual night (yes, ≤ 6 h; no, > 6 h)[47].

Preterm birth (yes or no) was considered an ancestral variable of anthropometric trajectory exposure because it represented a direct cause of low birth weight. Information on clinical history of chronic diseases (cancer, chronic obstructive pulmonary disease and liver or kidney disease) reported at the study baseline was considered for the variable presence of debilitating chronic diseases (yes, prevalence of these diseases; no, absence). The covariates age at menarche (< 12 or ≥ 12 years) and menopause (yes or no) were also considered for women.

Data analysis

A theoretical model for analysing the causal effect between anthropometric trajectory and sarcopenia was prepared based on directed acyclic graphs (DAG) using the software DAGitty 2·3 ® (Fig. 2). The DAG allows to graphically represent theoretical assumptions regarding associations between exposure and outcome and adequately control confounding factors considered in the causal model[48]. Based on heuristic rules, the proposed DAG to estimate the total effect of the anthropometric trajectory on the occurrence of sarcopenia considered a minimally sufficient adjustment set[49] of variables, such as leisure-time physical activity, presence of debilitating chronic diseases, diabetes, sleep duration, age group, skin colour and menopause (women).

All analyses were stratified by sex and considered differences in the proportion of skeletal muscle mass between men and women. Data sequence analysis using the sq command in the Stata® MP software (version 14.0) identified the main trajectories among participants to identify changes in anthropometric trajectories throughout life. This procedure of combinatorial data analysis has been used to analyse health risk factors throughout life[50,51] in epidemiological studies. Sequences of patterns of change in anthropometric trajectory were used as predictive variables for sarcopenia in men and women from the ELSA-Brasil cohort.

A descriptive analysis characterised sarcopenia and the anthropometric trajectory according to study covariates. Differences between groups were identified using Pearson's χ^2 test, adopting a *P*-value ≤ 0·05. Poisson regression with robust variance was used to test the crude and total effect models, considering the minimum adjustment suggested by the DAG for the association between exposure (anthropometric trajectory throughout life) and outcome (sarcopenia). The prevalence ratio (PR) and 95 % CI were estimated. The Stata®, version 14.0, software was used for the statistical analysis.
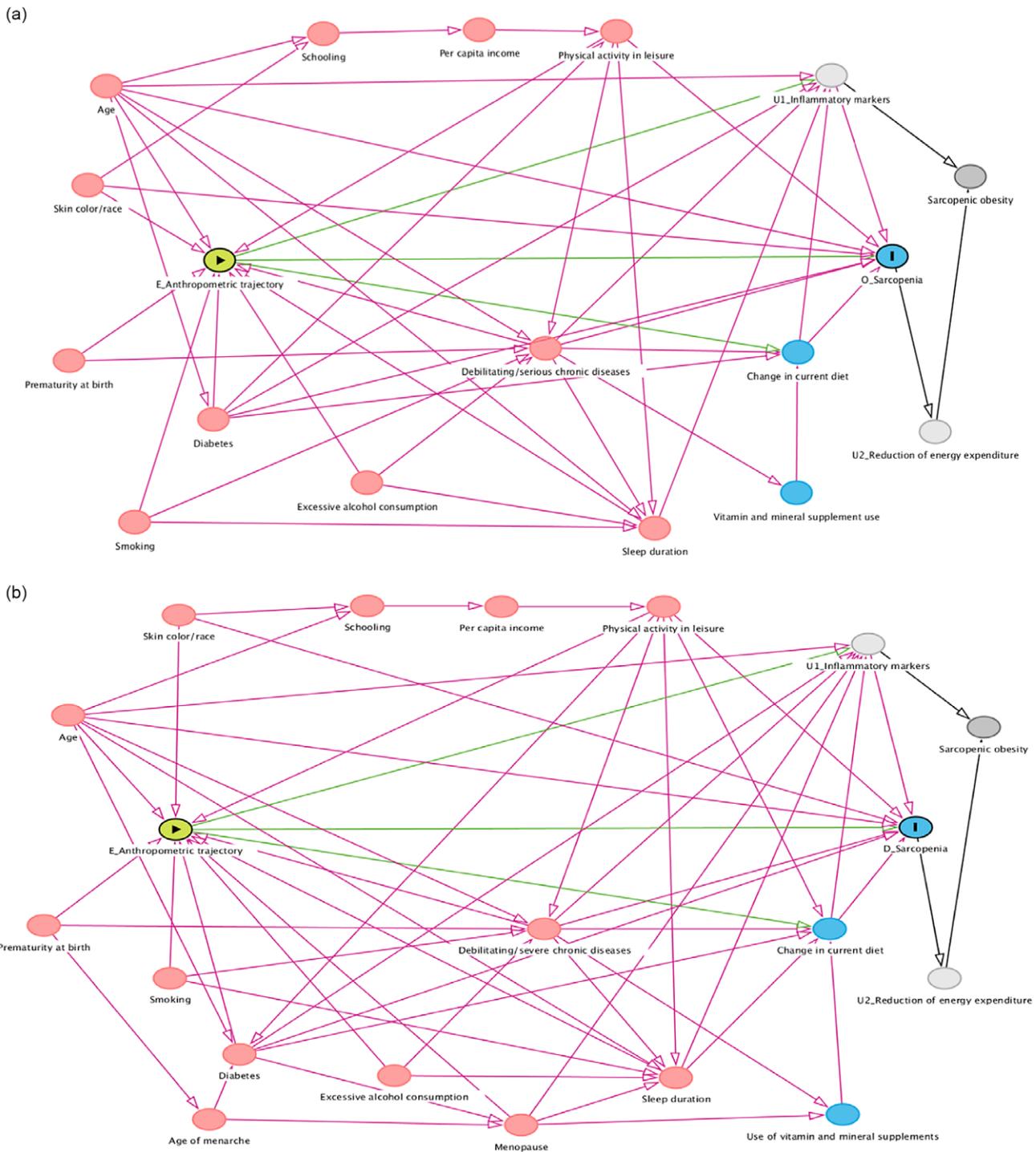
Fig. 2. Directed acyclic graphs (DAG) for association between change pattern in anthropometric trajectory during the life course of life and sarcopenia for men (a) and women (b). ⊙, Exposure; ⊙, Outcome; ⬤, Ancestor of exposure; ⬤, Ancestor of outcome; ⬤, Ancestor of exposure and outcome; ◯, Adjusted variable; ◯, Unobserved (latent); ⬤, Other variable; ▬, Causal path; ▬, Biasing path.

Results

A total of 4448 (46·00 %) men and 5222 (54·00 %) women were included in this study. Table 1 shows the five most frequent anthropometric trajectories among the fifty-four pattern sequences identified. Anthropometric trajectories were classified based on patterns of change in BMI categories (i.e. increase, decrease, stable and body weight fluctuation). Patterns of change to overweight (63·90 %) and stable weight (17·08 %) throughout life were the most frequent; the former was also the most prevalent: 65·20 % of men and 62·79 % of women (Graph 1).
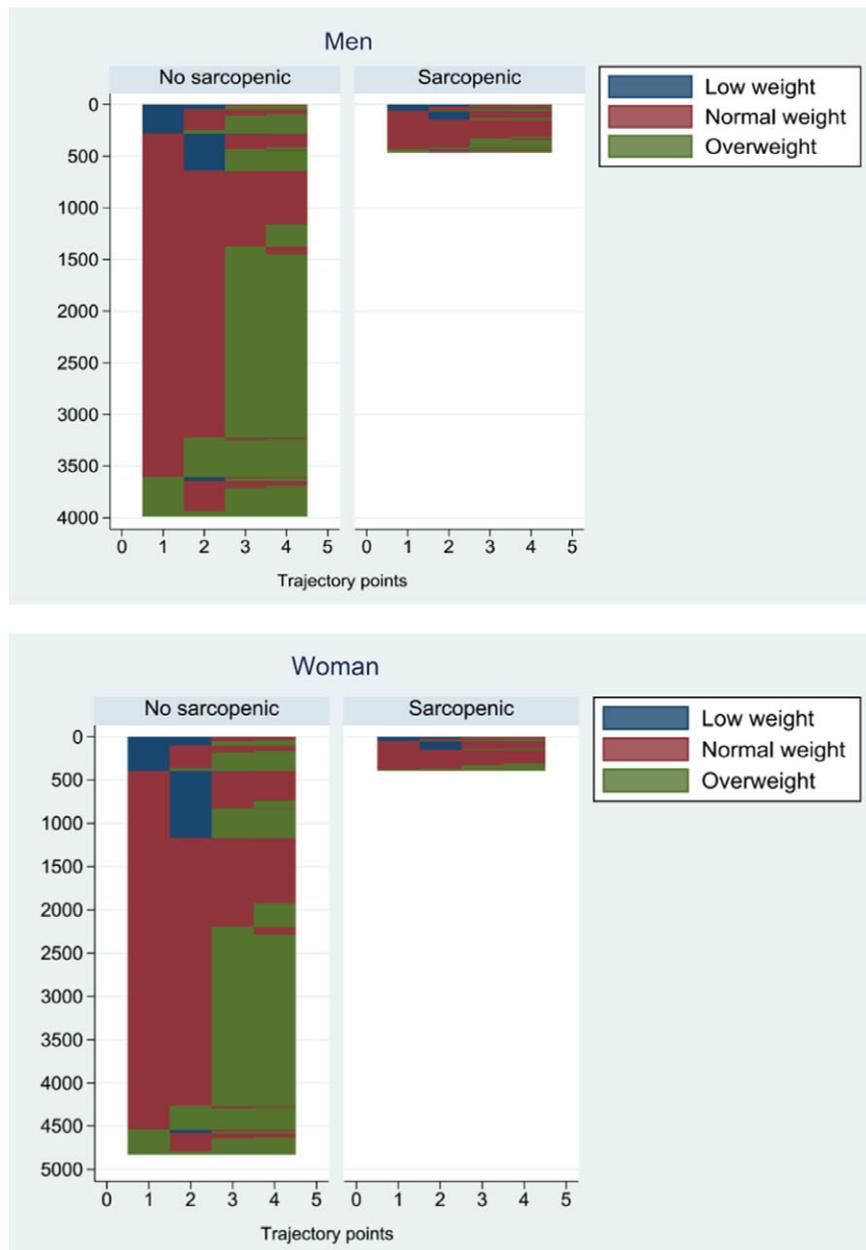
Graph 1. Sequence patterns of anthropometric trajectories identified at different points in the life course of men (a) and women (b) of the ELSA-Brasil cohort (2008–2010) and (2012–2014), according to state of sarcopenia

Table 2 presents significant differences in the prevalence of sarcopenia in the studied population. Most men (41·90 %) and women (43·26 %) younger than 55 years old had sarcopenia; 62·04 and 72·63 % self-reported white skin colour, respectively. A total of 58·67 % of women with sarcopenia reported sleeping > 6 h/night, 74·81 % had menopausal status and 35·20 % had debilitating chronic diseases. Moreover, 40·20 % had an anthropometric trajectory marked by stable weight, 24·68 % by weight fluctuation and 21·12 % by change to overweight. Regarding men with sarcopenia, 12·12 % reported diabetes, while 37·15 % had an anthropometric trajectory of stable weight, 24·42 % changed to overweight and 23·60 % of weight fluctuation. A total of 82·59 % of patients with sarcopenia started

the anthropometric trajectory with normal weight and 13·08 % with low birth weight.

Tables 3 and 4 show the patterns of anthropometric trajectory according to the minimally sufficient adjustment covariates selected in the DAG. Most men and women aged between 38 and 54 years, self-declared white, were not active during leisure time and did not present a significant prevalence of debilitating chronic diseases. Most women reported short sleep duration and menopausal status. Data showed significant differences between patterns of change in anthropometric trajectory and physical activity during leisure time ($P = 0·05$). We also observed that most active men had a pattern of stable weight (54·38 %) and weight fluctuation (50·08 %). Patterns of change to overweight and low weight were more frequent

Table 2. Prevalence of sarcopenia according to characteristics of men and women participating in the Longitudinal Study of Adult Health (ELSA-Brasil) (2012–2014)
(Numbers and percentages)

	Sarcopenia					
	Total		Men		Women 4	
Characteristics	n	%	n	%	n	%
Age (years)						
38–54 years	364	42·52*	194	41·90*	170	43·26*
55–64 years	305	35·63	155	33·48	150	38·17
≥ 65 years	187	21·85	114	21·7	73	18·58
Skin colour						
Black	68	7·98*	40	8·68*	28	7·16*
Brown	214	25·12	135	29·28	79	20·20
White	570	66·90	286	62·04	283	72·63
Physical activity in leisure						
No	481	56·19	256	55·29	225	57·25
Yes	375	43·81	207	44·71	168	42·75
Sleep duration						
≤ 6 h/night	392	45·90*	230	49·78	161	41·33*
> 6 h/night	462	54·10	232	50·22	230	58·67
Menopause						
No	–		–		99	25·19*
Yes	–		–		294	74·81
Serious chronic diseases						
No	559	65·61*	305	66·30	254	64·80*
Yes	293	34·39	155	33·70	138	35·20
Diabetes						
No	774	90·53	406	87·88*	368	93·64
Yes	81	9·47	56	12·12	25	6·36
Birth weight classification						
Low weight	112	13·08*	65	14·04*	47	11·96*
Normal weight	707	82·59	370	79·91	337	85·75
Overweight	37	4·32	28	6·05	9	2·29
Anthropometric trajectory						
TI – Stable weight	318	37·15*	160	34·56*	158	40·20*
T2 – Change to normal weight	99	11·57	56	12·10	43	10·94
T3 – Change to overweight	209	24·42	126	27·21	83	21·12
T4 – Body weight fluctuation	202	23·60	105	22·68	97	24·68
T5 – Change to low weight	28	3·27	16	13·46	12	3·05

* $P < 0·05$.
The analysed data met the criteria for using the χ^2 test (less than 20 % of the expected frequencies were <5 and no cell has an expected value <1).

among inactive men. A high frequency of diabetes was observed in men with a trajectory of change to overweight (9·93 %) and weight fluctuation (7·40 %). Furthermore, 10·41 % of men presented sarcopenia, which was significantly higher among those with a trajectory of change to low weight (61·54 %).

Regarding women, the trajectories of change to normal weight and weight fluctuation were significantly more frequent in those younger (53·53 and 53·58 %, respectively), white (59·24 and 61·42 %) and who presented insufficient leisure-time activity (53·53 and 58·16 %), short sleep duration (51·67 and 52·23 %) and menopausal status (63·07 and 66·40 %). Patterns of stable weight and change to overweight were more frequent among young women (58·41 and 49·01 %), white (69·57 and 53·42 %) and in menopausal status (60·66 and 73·22 %). Additionally, the pattern of change to overweight was more frequent among women insufficiently active in leisure time (65·84 %) and with sleep duration > 6 h (50·47 %), whereas the highest frequency of stable weight was observed among those sufficiently active at leisure time (52·09 %) and with sleep duration ≤ 6 h (55·47 %). Patterns of change to low weight were higher among women aged between

55 and 64 years (50·00 %), white (67·86 %), insufficiently active (75·00 %) and in menopausal status (82·14 %). A high prevalence of diabetes was also observed in participants with a pattern of change to overweight (9·10 %) and normal weight (7·88 %). Sarcopenia was observed in 7·52 % of women and was more frequent in trajectories with a pattern of change to low weight. The differences observed in women were statistically significant, except for excessive alcohol consumption and presence of debilitating chronic diseases (Table 4).

Table 5 presents the results of Poisson regression with robust variance for the association between patterns of change in the anthropometric trajectory and occurrence of sarcopenia in men and women from the ELSA-Brasil. Sarcopenia in men and women was inversely associated with patterns of change to overweight (PR = 0·18; 95 % CI (0·15, 0·23) and PR = 0·15; 95 % CI (0·11, 0·19)) and weight fluctuation (PR = 0·76; 95 % CI (0·61, 0·96) and PR = 0·77; 95 % CI (0·61, 0·97)). Additionally, sarcopenia was 2-fold more frequent among men (PR = 2·73; 95 % CI (1·92, 3·88)) and women (PR = 2·28; 95 % CI (1·46, 3·56)) with a pattern of change to low weight. The associations observed

Table 3. Distribution of men participating in the study according to patterns of change in the anthropometric trajectory in the course of life. Longitudinal Study of Adult Health (ELSA-Brasil) (2008–2010) and (2012–2014)
(Numbers and percentages)

	Men (n 4448)												
	Anthropometric trajectory												
	Total		T1 – Stable weight		T2 – Change to normal weight		T3 – Change to overweight		T4 – Oscillation weight		T5 – Change to low weight		
	n	%	n	%	n	%	n	%	n	%	n	%	P*
Age (years)													
38 to 54 years	2346	52·74	397	55·22	99	51·03	1522	52·48	315	51·72	13	50·00	0·434
55 to 64 years	1444	32·46	211	29·35	62	31·96	945	32·59	216	35·47	10	38·46	
≥ 65 years	658	14·79	111	15·44	33	17·01	433	14·93	78	12·81	3	11·54	
Skin colour													
Black	551	12·55	73	10·27	21	11·05	387	13·52	68	11·31	2	7·69	0·140
Brown	1307	29·77	196	27·57	63	33·16	861	30·07	179	29·78	8	30·77	
White	2533	57·69	442	62·17	106	55·79	1615	56·90	354	58·90	16	61·54	
Physical activity in leisure													
No	2275	51·15	328	45·62	97	50·00	1530	52·76	304	49·02	16	61·54	0·009
Yes	2173	48·85	391	54·38	97	50·00	1370	47·24	305	50·08	10	38·46	
Sleep duration													
≤ 6 h/night	2153	48·44	376	52·29	84	43·30	1381	47·64	299	49·26	13	50·00	0·122
> 6 h/night	2292	51·56	343	47·71	110	56·70	1518	52·36	308	50·74	13	50·00	
Serious chronic diseases													
No	3097	69·82	506	70·47	135	69·5 9	2010	69·5 3	427	70·23	19	76·00	0·927
Yes	1339	30·18	212	29·53	59	30·41	881	30·47	181	29·77	6	24·00	
Diabetes													
No	4068	91·50	686	95·54	182	93·81	2612	90·07	563	92·60	25	96·15	<0·001
Yes	378	8·50	32	4·46	12	6·19	288	9·93	45	7·40	1	3·85	
Sarcopenia													
No	3985	89·59	559	77·75	138	71·13	2774	95·66	504	82·76	10	38·46	<0·001
Yes	463	10·41	160	22·25	56	28·87	126	4·34	105	17·24	16	61·54	

* The analysed data tended to the criteria for using the χ^2 test (less than 20 % of the expected frequencies were <5 and no cell has an expected value <1).

in this study remained even after adjusting for the confounding factors suggested in the DAG.

Discussion

The anthropometric trajectory characterised by a pattern of change to low weight was positively associated with sarcopenia in adult men and women from the ELSA-Brasil cohort, corroborating the literature[29,52–54]. Our findings also showed that men with a pattern of change to low weight were less active during leisure time. Besides, the trajectory of change to low weight in women was more frequent in those aged between 55 and 64 years, white and experiencing menopause.

Differences in skin colour related to the pattern of change to low weight were also shown by Byrne *et al.*[55] and can be justified by the increased metabolism of organic tissue located in trunk and decreased amount of muscle tissue in the lower segments in white women[55]. Additionally, the conditions observed in men and women with low weight may lead to inflammatory processes, metabolic alterations and increased energy uptake (i.e. degradation of amino acids stored in muscles), thus contributing to the increased occurrence of sarcopenia[56–61].

An important point highlighted in our study was the association between low birth weight and sarcopenia in adulthood, in which most participants who started the anthropometric trajectory with low birth weight presented sarcopenia in adulthood regardless of the subsequent pattern of anthropometric trajectory. This result is consistent with literature and suggests a strong association between birth weight and increased fat mass[21,23], reduced lean mass[16,17] and low muscle strength performance[19,20] in adults.

In Brazil, data from the birth cohort conducted in Pelotas (Rio Grande do Sul) showed a positive association between birth weight and muscle mass in early adulthood. Besides, the study by Victora *et al.*[23] indicated that weight gain at the beginning of adulthood was associated with increased fat and lean mass. These relationships may be interpreted in the context of low- and middle-income countries, where birth weight and weight trajectory in the first 2 years of life are strong predictors of lean mass in adulthood[22]. Birth weight was also an indicator of adverse outcomes related to body composition in adulthood in the ELSA-Brasil, with associations between low birth weight, diabetes and measures of glucose homoeostasis in men and women[62].

The anthropometric trajectory with a pattern of change to overweight after 35 years old was a protective factor for sarcopenia, even after adjusting for confounding factors identified in the DAG. These results were similar to findings of Cooper *et al.* in a British birth cohort, in which increased BMI gains after 15 years old reduced the OR of sarcopenia by 65 %[13]. According to authors, although excessive body mass may be a protective factor (OR = 0·35; 95 % CI (0·28, 0·43)) for maintaining skeletal

Table 4. Distribution of women participating in the study according to patterns of change in the anthropometric trajectory in the course of life. Longitudinal Study of Adult Health (ELSA-Brasil) (2008–2010) and (2012–2014)
(Numbers and percentages)

	Women (n 5222)											
	Anthropometric trajectory											
	Total		T1 –Stable weight		T2 – Change to normal weight		T3 - Change to overweight		T4 – Oscillation weight		T5 – Change to low weight		P *
	n	%	n	%	n	%	n	%	n	%	n	%	
Age (years)													
38–54 years	2689	51·49	545	58·41	129	53·53	1607	49·01	397	53·58	11	39·29	<0·001
55–64 years	1790	34·28	273	32·90	79	32·78	1177	35·90	247	33·33	14	50·00	
≥ 65 years	743	14·23	115	12·33	33	13·69	495	15·1	97	13·09	3	0·71	
Skin colour													
Black	871	16·8 0	89	9·57	24	10·08	648	19·90	105	14·36	5	17·86	<0·001
Brown	1317	25·41	194	20·86	73	30·67	869	26·68	177	24·21	4	14·29	
White	2996	57·79	647	69·57	141	59·24	1740	53·42	449	61·42	19	67·86	
Physical activity in leisure													
No	3187	61·03	447	47·91	129	53·53	2159	65·84	431	58·16	21	75·00	<0·001
Yes	2035	38·97	486	52·09	112	46·47	1120	34·16	310	41·84	7	25·00	
Sleep duration													
≤ 6 h/night	2663	51·07	517	55·47	124	51·67	1621	49·53	387	52·23	14	50·00	0·029
> 6 h/night	255	48·93	415	44·53	116	48·33	1652	50·47	354	47·77	14	50·00	
Menopause													
No	1588	30·41	367	39·34	89	36·93	878	26·78	249	33·60	5	17·86	<0·001
Yes	3634	69·59	566	60·66	152	63·07	2401	73·22	492	66·40	23	82·14	
Serious chronic diseases													
No	3722	71·54	673	72·44	168	70·00	2337	71·47	528	71·74	16	527·14	0·474
Yes	1481	28·46	256	27·56	72	30·00	933	28·53	208	28·26	12	42·86	
Diabetes													
No	4809	92·18	888	95·18	222	92·12	2977	90·90	696	94·05	26	92·86	<0·001
Yes	408	7·82	45	7·82	19	8·88	298	9·10	44	5·95	2	7·14	
Sarcopenia													
No	482	92·47	775	83·07	198	82·16	3196	97·47	644	86·91	16	57·14	<0·001
Yes	393	7·53	158	16·93	43	17·84	83	2·53	97	13·09	12	42·86	

* The analysed data met the criteria for using the χ^2 test (less than 20 % of the expected frequencies were <5 and no cell has an expected value <1).

muscle mass in adults (especially older adults), the quality of performance of this muscle mass may be impaired (OR = 1·47; 95 % CI (1·25, 1·74)) due to weight accumulation throughout adulthood.

Koster et al. also found increased skeletal muscle mass with weight gain in a study conducted with older adults aged between 70 and 79. However, after 7 years of follow-up, men and women with increased body fat showed a more pronounced decline in muscle mass[25] and greater damage to the quality of muscle performance with weight gain, indicating that increased lean mass in individuals with excessive weight does not improve muscle performance. Besides, inflammatory changes and insulin resistance caused by increased adipose tissue may explain the fast decline in muscle mass. These changes may contribute to muscle mass decline in older adults since the metabolic load in muscles of individuals with overweight may overcome the ability to synthesise the stored protein[56,63].

Chronic diseases may also lead to inflammatory and metabolic processes and pronounced loss of muscle mass and strength, even in individuals under adequate diet[63,64]. According to previous evidence, chronic diseases may increase the lean mass decline by 4·5–30 % compared with the normal loss attributed to ageing. Additionally, diabetes enhances this

decline by approximately 30 %[57], corroborating the increased prevalence of sarcopenia in men with diabetes from our study.

The protective effect against sarcopenia among individuals with a pattern of change to overweight is supported by the fact that weight gain throughout life may reflect an increase in muscle mass, but not fat mass, especially if accompanied by physical activity. This effect may also indicate cyclical changes in dietary behaviour for weight loss. Nevertheless, the use of cross-sectional data cannot ensure that changes in physical activity and diet throughout life influence the pattern of change to overweight.

Weight stability, especially normal weight, and reduction of overweight are important strategies for health promotion and disease prevention[31–33], including sarcopenia[65]. However, empirical data have considered a paradoxical relationship between weight gain and health, especially in middle-aged and older adults. The literature shows a favourable prognosis for some diseases and a low risk of mortality in adults with overweight compared with normal or low weight[66–69]. Despite that, improvements in public health, technology and medical care may have reduced the impact of obesity on mortality, confusing the observed evidence.

Our findings also suggest an obesity paradox related to sarcopenia, similar to literature[70]. This interaction may occur

Table 5. Crude and adjusted association between pattern of changes in the anthropometric trajectory in the course of life and sarcopenia in men and women. Longitudinal Study of Adult Health (ELSA-Brasil) (2008–2010) and (2012–2014)
(Prevalence ratios and 95 % confidence intervals)

Anthropometric trajectory	Model 1*		Model 2	
	PR	95 % CI	PR	95 % CI
Men†				
TI – Stable weight	1		1	
T2 – Change to normal weight	1·29	1·00, 1·68	1·25	0·96, 1·62
T3 – Change to excess weight	0·19	0·15, 0·24	0·18	0·15, 0·23
T4 – Body weight fluctuation	0·77	0·62, 0·96	0·76	0·61, 0·95
T5 – Change to low weight	2·76	1·98, 3·85	2·73	1·92, 3·88
Women‡				
TI – Stable weight	1		1	
T2 – Change to normal weight	1·05	0·77, 1·43	1·08	0·80, 1·47
T3 – Change to excess weight	0·14	0·11, 0·19	0·15	0·11, 0·19
T4 – Body weight fluctuation	0·77	0·61, 0·97	0·77	0·61, 0·97
T5 – Change to low weight	2·53	1·61, 3·97	2·28	1·46, 3·56

* Crude model of the association between sarcopenia (outcome) and different patterns of change in the anthropometric trajectory throughout life.
† Total effect model (men) considering the minimum necessary adjustment suggested by the DAG – adjusted for leisure-time physical activity, presence of serious chronic diseases (chronic obstructive pulmonary disease, chronic kidney disease, liver disease, cancer), sleep duration, age group (years) and skin colour.
‡ Total effect model (women) considering the minimum necessary adjustment suggested by DAG – adjusted for leisure-time physical activity, presence of serious chronic diseases (chronic obstructive pulmonary disease, chronic kidney disease, liver disease, cancer), diabetes, sleep duration, age group (years), menopause and skin colour.

because obese individuals tend to have increased lean mass due to increased total body mass. Another explanation is that body weight gains due to reduced energy expenditure from ageing and sedentarism may be more pronounced than skeletal muscle mass decline. This would imply the preservation of muscle mass among those with a pattern of change to overweight during adulthood. In this sense, the risks related to overweight should be considered when formulating health promotion and prevention policies for chronic diseases, especially during adulthood. Furthermore, increasing evidence suggests a positive relationships between overweight and development of cardiometabolic disorders[26,27], increased risk of mortality[28,30], worse muscle quality and pronounced lean mass decline during ageing[13,25].

The combination of obesity and sarcopenia characterises sarcopenic obesity. Although its diagnosis is not currently standardised, this condition has been associated with worse physical and functional status and increased risk of morbidity and mortality[71,72]. Data revealed an increase of 23 % in the risk of CVD in individuals with sarcopenic obesity[73] and a prevalence of sarcopenic obesity of approximately 8 and 11-fold higher than isolated sarcopenia and obesity, respectively[74]. Although a recent study showed positive associations between excessive body weight, progression of sarcopenia and increased risk of mortality[75], future studies are needed to improve the understanding of these relationships.

This study was the first to identify patterns of anthropometric trajectory related to sarcopenia using a longitudinal design that included a large and nationally representative sample of civil servants of both sexes living in six Brazilian capitals. Literature lacks data regarding the effects of patterns of change in

anthropometric trajectories from birth to adulthood, the variability of these trajectories and their effects on the occurrence of sarcopenia in adults. The suggested relationships were based on specific anthropometric measurements collected at specific time points without considering the trajectory of change throughout life[52–54].

Only one study using data from the British birth cohort demonstrated the influence of BMI trajectory from 15 years old on the quantity and quality of muscle mass at early old age[13]. Our findings partially corroborate this study since associations between patterns of anthropometric trajectory and muscle mass quality were not investigated in our study.

This study has some limitations. Our findings should be cautiously considered for the general population of Brazilian adults since data were extracted from a population of civil servants sharing similar characteristics. Thus, worker bias cannot be ruled out. The patterns of change in anthropometric trajectory were partially based on self-reported information regarding birth weight (used to express muscle mass at this stage of life) and body weight at 20 years (used to calculate BMI). Although memory bias cannot be excluded, the validity of these measures has been indicated in studies with different socio-demographic groups[76,77].

Importantly, BMI does not discriminate body components; in contrast, it may reflect lean and fat mass changes and mitigate the probability of sarcopenia, suggesting an obesity paradox. Furthermore, the cut-off points used to categorise strength decline were adjusted by age group, while the estimation of decreased skeletal muscle mass was based on normative data from the younger adult population of the ELSA-Brasil, which might have overestimated the occurrence of sarcopenia in the population.

The sample size related to the pattern of change to low weight was also considered a limiting factor in this study. However, the assumptions that defined the patterns of change based on sequence analysis may represent an initial advance for understanding the health consequences of different anthropometric trajectories throughout life. Further analyses of patterns of change considering the development of peak muscle mass throughout adulthood and using robust analytical strategies for longitudinal data could be incorporated in future studies on sarcopenia and other health outcomes obtained in the ELSA-Brasil.

We conclude that the increased occurrence of sarcopenia among men and women with an anthropometric trajectory characterised by changes to low weight and the protective effect observed in the pattern of change to overweight demonstrated muscle plasticity to adapt to body changes throughout life. This plasticity may also occur in adverse metabolic situations or due to ageing, illness and unhealthy lifestyles. In this sense, future investigations using longitudinal data obtained from the ELSA-Brasil are needed to assess the quality of muscle mass performance and progression of sarcopenia in participants with an anthropometric trajectory of change to overweight. Last, another valid topic for future research is the stage of life in which overweight and obesity would imply a high occurrence of sarcopenia.

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