Patient Education and Counseling xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Patient Education and Counseling

journal homepage: www.elsevier.com/locate/pec

Patient-centered innovation

Health Literacy throughout adolescence: Invariance and validity study of three measurement scales in the general population

Alexandra Rouquette[a,b,*], Laurent Rigal[c,d], Julien Mancini[e,f], Francis Guillemin[g,h], Stephan van den Broucke[i], Cécile Allaire[j], Sylvie Azogui-Levy[k,l], Virginie Ringa[c], Christine Hassler[a]

[a] Paris-Saclay University, UVSQ, Inserm, CESP, Paris, France
[b] APHP Paris-Saclay, Epidemiology and Public Health Department, Le Kremlin-Bicêtre, France
[c] Paris-Saclay University, UVSQ, Inserm, CESP, Villejuif, France
[d] Paris-Saclay University, Medicine Faculty, General Practice Department, Le Kremlin-Bicêtre, France
[e] Aix Marseille University, Inserm, IRD, SESSTIM, Cancer, Biomedicine & Society group, Marseille, France
[f] APHM, BIOSTIC, Timone Hospital, Marseille, France
[g] CHRU-Nancy, INSERM, Lorraine University, CIC 1433 Clinical Epidemiology, Vandoeuvre-les-Nancy, France
[h] Lorraine University, APEMAC, Vandœuvre-lès-Nancy, France
[i] Psychological science Research Institute, Louvain Catholic University, Louvain-la-Neuve, Belgium
[j] Santé publique France, Saint-Maurice, France
[k] Department of Dental Public Health, Faculty of Dentistry, Paris Diderot University, Paris, France
[l] Education and Health Practices Laboratory (LEPS) (EA 3412), UFR SMBH, Paris 13 University, Sorbonne Paris Cité, Bobigny, France

ARTICLE INFO

Article history:
Received 21 March 2021
Received in revised form 5 June 2021
Accepted 27 July 2021
Available online xxxx

Keywords:
Health literacy
Adolescence
Psychometric properties
HLSAC
HAS-A
HLS-EU-Q16

ABSTRACT

Objective: To simultaneously investigate the psychometric properties of three recently developed health literacy measurement scales throughout adolescence in the general population.
Methods: French versions of the Health Literacy for School-Aged Children (HLSAC, unidimensional) scale, the Health Literacy Assessment Scale for Adolescents (HAS-A, multidimensional) and the 16-item European Health Literacy Survey questionnaire (HLS-EU-Q16, unidimensional) were completed by 1 444 adolescents in 8th, 9th, 11th grade in general school and 11–12th grade in vocational school. Psychometric properties were studied using confirmatory factor analysis, McDonald's omega coefficient and hypothesis testing.
Results: Structural validity was acceptable (HLS-EU-Q16) to good (HAS-A and HLSAC), no measurement invariance issue was found and internal consistency was acceptable for the three scales (0.68–0.84). Convergent validity was low (Pearson correlation coefficients < 0.5) and the only scale for which results were in agreement with a priori hypotheses was the HLSAC.
Conclusions: Our results were supportive of the use of HLSAC to assess health literacy during adolescence but the HAS-A, with a slightly better structural validity, can also be promoted due to its three measured dimensions.
Practice implications: The use of these scales in practice will help to focus on health literacy, a critical factor for prevention and health promotion in adolescence.

1. Introduction

Health literacy (HL) has been defined as "*the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways that promote and maintain good health*" [1]. Interest in this concept has been growing in the public health literature since the 2000 s, owing to the works of Nutbeam, Osborne et al., or the European HL Survey group, among others, who have developed conceptual models for a more precise understanding of HL [2–4]. All these models encompass the three

* Correspondence to: Inserm, CESP, Maison de Solenn, 97 Boulevard de Port Royal cedex 14, 75679 Paris, France.
E-mail addresses: alexandra.rouquette@inserm.fr (A. Rouquette), laurent.rigal@free.fr (L. Rigal), julien.mancini@inserm.fr (J. Mancini), francis.guillemin@chru-nancy.fr (F. Guillemin), stephan.vandenbroucke@uclouvain.be (S. van den Broucke), cecile.allaire@santepubliquefrance.fr (C. Allaire), sylvie.azogui-levy@paris7.jussieu.fr (S. Azogui-Levy), virginie.ringa@inserm.fr (V. Ringa), christine.hassler@inserm.fr (C. Hassler).

https://doi.org/10.1016/j.pec.2021.07.044
0738-3991/

aspects of the modern conceptualization of HL: *functional HL*, which involves basic skills (reading, writing, etc.) and allows access to health information; *interactive HL*, which uses more advanced cognitive skills to understand this information; and finally *critical HL*, which involves in-depth cognitive and social skills leading ultimately to better control of life events [4].

Several studies have shown links between low HL and poor health status, limited survival, and higher health care costs [5–8]. The central role of HL in health inequities over the world was highlighted by the WHO, which regards HL as "a critical determinant of health" and a resource that "must be an integral part of the skills and competencies developed over a lifetime, first and foremost through the school curriculum" [1,9]. It is becoming increasingly clear that the HL can also be seen as a mediator of health inequalities [10–12]. However, most of the studies on HL have been conducted in adults and very little research, specifically involving the modern conceptualization of HL, have been conducted in adolescents [13–15].

Adolescence is often described as a period of opportunity for prevention and health promotion interventions because fundamental processes of cognitive, physical and emotional development are under construction during this period [10]. It is also at that time that independent decision-making begins [12]. It is therefore crucial to arm adolescents with accurate and reliable health information that can help them adopt healthy behaviors early in life and to continue these behaviors later. Good access to, understanding, critical appraisal and use of such information are thus necessary to enable them to take charge of their own health [12,13]. This is all the more essential in view of the widespread access to information via the Internet, which has raised serious concerns about the correctness and validity of the information that adolescents obtain.

A recent systematic review identified 29 HL measurement instruments used in children and adolescents, 15 of which measured all three the HL domains (functional, interactive and critical) [14]. Two of these instruments were brief and designed to be self-administered by adolescents from 13 years of age in general settings: the unidimensional Heath Literacy for School-Aged Children (HLSAC, S1 Table) with 10 items covering five core components of HL (theoretical knowledge, practical knowledge, critical thinking, self-awareness and citizenship), and the multidimensional Health Literacy Assessment Scale for Adolescents (HAS-A, S2 Table) with 15 items related to three dimensions ("Communication: communicating health information", "Confusion: confusion about health information" and "Functional HL: understanding health information") [15,16]. Although these measures have been developed in different samples, their measurement properties appear quite similar, despite some differences in terms of structural validity (more evidence for validity for HAS-A) and hypothesis testing (better agreement with a priori hypotheses for HLSAC). Another well-validated and widely used instrument to measure HL is the (unidimensional) 16-item European Health Literacy Survey (HLS-EU-Q16) [17–19]. This short version of the original 47-item Health Literacy Survey tool covers four health information processing skills (accessing, understanding, appraising, and applying health information) applied to three health contexts (healthcare, disease prevention, and health promotion) (S3 Table) [20]. Although the HLS-EU-Q16 was developed for use among adults in the general population, it has also been used with adolescents [18,19]. However, its measurement properties have never been specifically assessed for use amongst adolescents, and some studies suggest that it may not be well adapted for that purpose [21].

In order to enhance the use of HL as a critical factor in prevention and health promotion aimed at adolescents in the general population, this study aimed to investigate the psychometric properties of the HLSAC, HAS-A and HLS-EU-Q16 for use with young people in the age range between 13 and 19 years-old in a sample from the general population. In particular, the purpose was to assess measurement invariance across sex, as it is a characteristic that is almost systematically studied in all studies, and throughout adolescence, to ensure that the scales measure the same construct in an identical way throughout this developmental period, so they can be used to evaluate changes in HL level in longitudinal studies. An additional aim was to assess whether these 3 scales measure different or related HL constructs by investigating convergent validity.

2. Methods

2.1. Data collected

2.1.1. French version of the three HL scales

The HLSAC consists of 10 items of the form "I am confident that…", to be scored on 4-point Likert response scales ranging from "not at all true" to "absolutely true", leading to a total score ranging from 10 to 40 (high HL) (S1 Table). Thresholds may be applied to classify HL levels in three categories "low HL" (≤25), "moderate HL" (26–35) and "high HL" (> 35) [22]. In the development study, the Cronbach alpha was 0.93 and a one-factor confirmatory factor analysis (CFA) model had a good fit to the data [15].

The HAS-A consists of three subscales: communication, confusion and functional HL, composed of 5, 4 and 6 items respectively. Each item is to be scored on a 5-point Likert response scale leading to 3 subscale scores ranging from 0 to 20 (high communication related HL), 0–16 (low confusion related HL) and 0–24 (low functional HL) (S2 Table). In the development study, the Cronbach alpha was 0.77, 0.73 and 0.76 for the three subscales, respectively, which had been identified using an exploratory factor analysis [16].

The HLS-EU-Q16 consists of 16 items of the format "How difficult is it for you to …", to be scored on 4-point Likert response scales ranging from "very easy" to "very difficult". A total score ranging from 0 to 16 (high HL) is computed by dichotomizing the replies, with the "very easy" and "easy" categories merged into a score of 1 and the "difficult" and "very difficult" merged into 0), and summing the scores thus obtained for the 16 items (S3 Table). Two thresholds are commonly used to define three levels of HL: inadequate (≤8), problematic (> 8 and ≤12) and adequate (> 12)[19,23,24]. Psychometric properties were studied in adults using a Rasch analysis, and Cronbach alpha was 0.81[17,19,23].

Five French experts from various disciplines (epidemiology, psychometrics, general medicine, public health, health education) with very high levels of English language proficiency and an English-French translator independently translated the English versions of the HAS-A and HLSAC into French. A consensus meeting was then held to arrive to a consensual French version of the two scales. No back-translation was performed, as this has recently been proven unnecessary [25]. For the HLS-EU-Q16, the French version that had previously been validated for use among adults was used [17] (S1, S2 and S3 Tables).

2.1.2. Other characteristics

The French version of the three HL scales were compiled in a questionnaire along with questions on socio-demographic characteristics (age, sex, language spoken at home, parents' education), weight and height, and chronic diseases.

2.2. Samples

The protocol, approved by the National Institute of Health and Medical Research (Institut national de la santé et de la recherche médicale - Inserm) ethics review board (IRB00003888, 2018/11/12) described three steps in which adolescents were involved. Before the beginning of each step, a letter with information about the study was provided to the adolescent (age-adapted) and to his/her parent

(s) (if minor). The adolescent (and/or his/her parents) who did not want to participate to the study provided a signed non-participation form. At the beginning of each step, the study was presented to the adolescent, then each adolescent individually completed the questionnaire (i.e., 3 HL scales and other characteristics) and returned it in an urn in a sealed envelope to preserve anonymity.

2.3. Focus groups

The first step aimed to assess acceptability and comprehensiveness of each translated item of the three HL scales through two focus groups: 1) aged 11–13 years: 7 males, 5 females; 2) aged 14–17 years: 4 males, 6 females. After the completion of the questionnaire (from 15 to 35 min), a comprehensive discussion was held in each group to identify understanding difficulties and suggestions of change. The consensual French versions of the 3 HL scales were not modified following the focus group however a significant number of comprehension issues was expressed by adolescents aged 11–13 years, particularly concerning the HLS-EU-Q16. The readability level of the translations, assessed using the Flesch Readability Score adapted to texts written in French, was 75.5 (7th grade) for the HLSAC, 63.5 (8th – 9th grade) for the HAS-A, and 48 (undergraduate – bordering end of high-school) for HLS-EU-Q16 [26].

2.4. Pilot testing

The second step aimed to evaluate the quality of questionnaire completion in 4 classes in 3 schools in the Paris area (following the focus groups, we decided to remove the 7th grade pupils from the target population): 8th grade (N = 27, mean age=13.5 years, 18 males), 9th grade (N = 28, mean age=14.5 years, 13 males), 11th grade (N = 30, mean age= 16.6 years, 8 males) and 11th grade in a vocational school (N = 23, mean age=17.7 years, all males). Once all the adolescents had returned the questionnaires, a comprehensive discussion with the whole class was held to assess acceptability of the questionnaire. Only a slight change was made on the item 1 of the HAS-A which began with “Est-il facile pour vous…” (“Is it easy for you…”) which was turned in “Est-ce que ça vous arrive de…” (“Do you happen to…”) after this pilot testing. Most of the other comments concerned the HLS-EU-Q16 which was considered as too complicated to fill in.

2.5. Study of the psychometric properties

The last step aimed to assess the psychometric properties of the three HL scales in a large sample of adolescents in 8th, 9th, 11th grade in general school and 11–12th grade in vocational school. The minimal sample size was set at 1200 (300 in each grade [27]) and increased by 25% due to possible truancy, nonsensical answers to the questionnaire and general setback that could prevent an entire class from completing the questionnaire. To ensure representation (but not statistical representativeness) of the various social backgrounds that exist in France, four geographical areas were chosen in which middle and high-schools were randomly selected, in which classes of each needed grade were randomly selected: Aveyron (rural), Hautes Pyrénées (semi-rural), Haute Garonne (semi-urban), Paris (urban).

2.6. Statistical analyses

Categorical data were summarized as frequencies (%) and quantitative data as means ± standard deviation. Floor or ceiling effects at the scale level were considered to be present if more than 15% of respondents achieved the lowest or highest possible score, respectively [28]. At the item level, these effects were considered to be present if more than 75% answered the lowest or highest response category [29].

The structural validity of each HL scale was studied using confirmatory factor analysis (CFA) with a robust estimator for categorical data, the Weighted Least Square Means and Variances adjusted [30]. For each scale, the model fitted was the one described by the authors of the initial development study: one dimension for HLSAC and HLS-EU-Q16, three dimensions for HAS-A [15,16,23]. Model fit was assessed using the Comparative Fit Index (CFI, good fit if > 0.95, poor fit if < 0.90, acceptable fit otherwise) and the Root Mean Square Error Approximation (RMSEA, good fit if < 0.06, poor fit if > 0.1, acceptable fit otherwise) [31]. Measurement invariance was tested consecutively across groups defined by the grade and sex. A multigroup CFA and the classic three-step sequence were used to investigate configural, metric and scalar invariance, i.e. three different nested models having increasing constraints were fitted to test these three levels of invariance [32,33]. For grade invariance for example, the same model was hypothesized in the four grade groups and the sequence of nested model tests was: 1) configural invariance: unconstrained factor loadings and item thresholds; 2) metric invariance: factor loadings constrained to be equal across the four grades and unconstrained item thresholds; 3) scalar invariance: factor loadings and item thresholds constrained to be equal across the four grades. Each level of measurement invariance was considered to be present if the fit indices difference, ΔCFI and ΔRMSEA, between nested models was ≥ −0.01 and ≤ 0.015 respectively [34,35].

Internal consistency was assessed using McDonald’s omega coefficient (acceptable if ≥0.7) [36]. To assess convergent validity, the correlation between HL scores (and subscale scores) was assessed using Pearson coefficients (acceptable if > 0.6) and a weighted kappa coefficient (quadratic weights) was computed to assess concordance (acceptable if kappa > 0.6) between the classifications of HL level obtained using HLSAC and HLS-EU-Q16 [29,37]. Finally, for hypothesis testing, Cohen’s d (corrected for uneven group size if needed) was computed to assess effect size (considered as small if d=0.2, medium if d=0.5 and large if d=0.8) and mean score of each HL scale was compared, using one-way analyses of variance or Student *t*-tests between adolescents according to sex (a priori hypothesis: no difference), grade repetition (lower HL if grade repetition), parents educational level (higher HL for higher education levels), main language at home (higher HL for French), chronic disease (higher HL if chronic disease), weight classification (higher HL if normal weight) [19,38–44].

Statistical tests were two-sided and a p-value < 0.05 was considered significant. Analyses were performed using Stata v.14 software for data management and basic statistics and Mplus v7.4 software for the CFA, which implements full information maximum likelihood to handle missing data [30,45].

3. Results

The survey took place in 68 classes in 23 schools from Monday 9th to Friday 13th March 2020. As the national lockdown due to COVID-19 crisis took place in France the 16th of March, two vocational schools scheduled from Monday 24th to Friday 28th March because adolescents were in internship during the beginning of March could not be included in this study. Among the 1 490 adolescents who filled in the questionnaire, 9 gave nonsensical answers and 37 responded to less than half of the items of the three HL scales. The characteristics of the 1 444 adolescents included in this study are summarized in the Table 1 according to the grade. The sex-ratio was balanced except in vocational schools in which boys were in majority. A language other than French was spoken at home for a third of the sample and one parent had at least a post-secondary education degree for half of the adolescents. Overall, adolescents were less in overweight or obesity in our sample than in general population (14.7% compared to 18.2% in [46]) and the proportion of

Table 1
Characteristics of the sample according to the grade, N(%) unless otherwise stated.

	8th grade	9th grade	11th and 12th grades – vocational school	11th grade – general school	Total
N	357	387	285	415	1444
Age (years), median (Q1-Q3)	13 (13–14)	14 (14–15)	17 (16–17)	16 (16–17)	15 (14–16)
Girls	177 (49.6)	203 (52.4)	113 (39.7)	226 (54.5)	719 (49.7)
No grade repetition	331 (93.0)	363 (93.8)	190 (66.7)	368 (88.7)	1252 (86.8)
Live outside the family home	2 (0.6)	5 (1.4)	54 (19.6)	31 (7.6)	92 (6.5)
Main language at home					
French	215 (60.2)	235 (60.7)	198 (69.5)	299 (72.1)	947 (65.6)
French and other	128 (35.9)	139 (35.9)	73 (25.6)	107 (25.8)	447 (31.0)
Other	14 (3.9)	13 (3.4)	14 (4.9)	9 (2.2)	50 (3.5)
Parents education					
Both parents with high school or lower	58 (16.3)	71 (18.4)	92 (32.3)	70 (16.9)	291 (20.2)
At least one with post-secondary school	154 (43.1)	202 (52.2)	85 (29.8)	279 (67.2)	720 (49.4)
Unknown	145 (40.6)	114 (29.5)	108 (37.9)	66 (15.9)	433 (30.0)
Chronic disease	68 (19.4)	69 (18.4)	56 (20.1)	100 (24.6)	293 (20.8)
Weight classification*					
Under weight	40 (12.8)	42 (11.7)	43 (16.6)	40 (10.0)	165 (12.4)
Normal weight	234 (74.8)	265 (73.6)	171 (66.0)	311 (77.6)	981 (73.6)
Overweight	30 (9.6)	45 (12.5)	36 (13.9)	41 (10.2)	152 (11.4)
Obesity	9 (2.9)	8 (2.2)	9 (3.5)	9 (2.2)	35 (2.6)

*Adapted to sex and age, according to the International Obesity Task Force. Q1: first quartile, Q3: third quartile.

adolescents who reported a chronic disease was high (20.8%) but similar with what was found in 2014 in France [47].

The distribution of the answers to each item (of each) of the 3 HL scales is described in S4 Table. There was no ceiling or floor effect at the item level and the proportion of missing answers was always < 6%. At the scale level, a ceiling effect was observed for the HLS-EU-Q16 scale with 269 (21.0%) adolescents with the highest score as described in Fig. 1. Concerning structural validity, as shown in Table 2, a good fit was found for the three-dimension HAS-A model while only acceptable to good fit was found for unidimensional HLSAC model and acceptable fit for unidimensional HLS-EU-Q16 model. No measurement invariance issue across grades was found for the three HL scales, neither across sex (Table 2). The internal consistency was acceptable for every scale (nearly acceptable for the HAS-A confusion scale) with a McDonald's omega coefficient was 0.82 for HLSAC, 0.84 for HLS-EU-Q16 and 0.73, 0.68 and 0.77 for the communication, confusion and functional HAS-A subscales respectively.

Convergent validity was low. Pearson correlation coefficients between HL scales were all < 0.6 (0.40, −0.21, −0.34 and 0.47 between HLSAC and HAS-A communication, confusion, functional subscales and HLS-EU-Q16 respectively; 0.38, −0.29 and −0.36

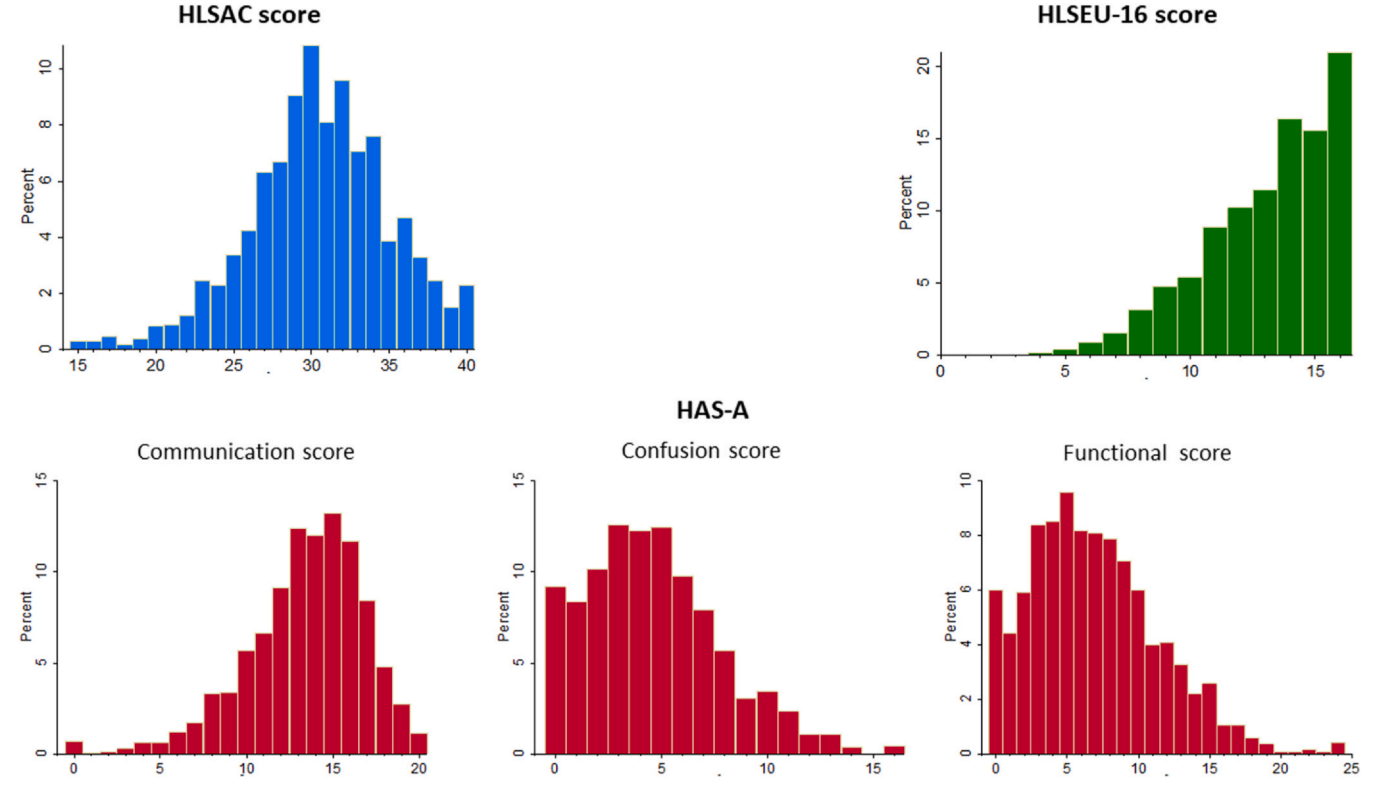

Fig. 1. Distribution of the score for the Heath Literacy for School-Aged Children (HLSAC), the Health Literacy Assessment Scale for Adolescents (HAS-A) and 16-item European Health Literacy Survey (HLS-EU-Q16) scales in the whole sample.

Table 2
Fit indices of the factor models and study of measurement invariance across grade and sex for the Heath Literacy for School-Aged Children (HLSAC), the Health Literacy Assessment Scale for Adolescents (HAS-A) and 16-item European Health Literacy Survey (HLS-EU-Q16).

Characteristic	Invariance model (constraints)	Chi-square (DF)	CFI	RMSEA (90%CI)	ΔCFI	ΔRMSEA
Grade	HLSAC					
	Configural (no constraints)	504.0 (140)	0.950	0.086 (0.078–0.094)	–	–
	Metric (loadings)	478.1 (167)	0.957	0.072 (0.065–0.080)	0.007	-0.014
	Scalar (loadings, thresholds)	578.2 (224)	0.951	0.067 (0.060–0.073)	-0.006	-0.005
	HAS-A					
	Configural (no constraints)	718.7 (348)	0.961	0.054 (0.049–0.060)	–	–
	Metric (loadings)	723.9 (384)	0.964	0.050 (0.044–0.055)	0.003	-0.003
	Scalar (loadings, thresholds)	938.4 (510)	0.954	0.048 (0.043–0.053)	-0.010	-0.002
	HLS-EU-Q16					
	Configural (no constraints)	1221.4 (416)	0.920	0.074 (0.069–0.078)	–	–
	Metric (loadings)	1345.9 (461)	0.912	0.073 (0.069–0.078)	-0.008	-0.001
	Scalar (loadings, intercepts)	1315.4 (527)	0.921	0.065 (0.060–0.069)	0.009	-0.008
Sex	HLSAC					
	Configural (no constraints)	359.7 (70)	0.959	0.076 (0.069–0.084)	–	–
	Metric (loadings)	324.1 (79)	0.966	0.066 (0.059–0.074)	0.007	-0.010
	Scalar (loadings, thresholds)	405.1 (98)	0.957	0.066 (0.060–0.073)	-0.009	0.000
	HAS-A					
	Configural (no constraints)	533.5 (174)	0.962	0.054 (0.048–0.059)	–	–
	Metric (loadings)	523.1 (186)	0.964	0.050 (0.045–0.055)	0.002	-0.004
	Scalar (loadings, thresholds)	657.8 (228)	0.954	0.051 (0.047–0.056)	-0.010	0.001
	HLS-EU-Q16					
	Configural (no constraints)	1012.6 (208)	0.920	0.073 (0.069–0.078)	–	–
	Metric (loadings)	1018.1 (223)	0.921	0.071 (0.066–0.075)	0.001	-0.002
	Scalar (loadings, intercepts)	959.5 (246)	0.929	0.064 (0.059–0.068)	0.008	-0.007

DF: Degree of Freedom, CFI: Comparative Fit Indices, RMSEA: Root Mean Square Error Approximation, CI: Confidence interval.

Table 3
Concordance between health literacy levels according to the Heath Literacy (HL) for School-Aged Children (HLSAC) and the 16-item European Health Literacy Survey (HLSEU-16) scales. N (%), kappa coefficient= 0.1.

	HLSAC (score)		
HLSEU-16 (score)	Low HL (< 26)	Moderate HL (26–35)	High HL (> 35)
Inadequate HL (< 9)	35 (24.1)	38 (4.2)	2 (1.1)
Problematic HL (9–12)	64 (44.1)	284 (31.7)	10 (5.5)
Adequate HL (> 12)	46 (31.7)	574 (64.1)	170 (93.4)
Total	145 (100.0)	896 (100)	182 (100)

between HLS-EU-Q16 and HAS-A communication, confusion and functional respectively). The weighted kappa coefficient assessing the concordance between HL levels defined using HLSAC and HLS-EU-Q16 thresholds was equal to 0.24 with 620 (50.5%) adolescents classified as having an adequate HL according to HLS-EU-Q16 while classified as having low or moderate HL according to HLSAC (Table 3). Concerning hypotheses testing, as described in Table 4, the only scale for which results were in agreement with a priori hypotheses was the HLSAC with small to medium effect sizes according to Cohen's d (except for grade repetition for which only a tendency was observed). Results concerning the two other scales were rarely in agreement with a priori hypotheses.

Table 4
Hypotheses testing for the School-Aged Children (HLSAC), the Health Literacy Assessment Scale for Adolescents (HAS-A) and the 16-item European Health Literacy Survey (HLS-EU-Q16). *A priori* hypotheses concerning Health Literacy (HL) were: no difference between sex, higher HL in higher grades, higher HL in higher parents' education levels, higher HL for French as main language at home, higher HL if chronic disease, higher HL if normal weight. mean ± SD.

	HLSAC	HAS-A			HLS-EU-Q16
		Communication	Confusion*	Functional*	
Sex: Cohen d (p-value)	0.07 (0.180)	0.01 (0.887)	0.19 (< 0.001)	0.22 (< 0.001)	0.12 (0.028)
Girls	30.4 ± 4.5	13.4 ± 3.4	4.9 ± 3.1	7.4 ± 4.3	12.9 ± 2.7
Boys	30.7 ± 4.6	13.4 ± 3.4	4.3 ± 3.3	6.4 ± 4.6	13.3 ± 2.5
Grade repetition: Cohen d (p-value)	0.15 (0.076)	0.12 (0.135)	0.01 (0.873)	0.14 (0.080)	0.07 (0.394)
No	30.6 ± 4.5	13.5 ± 3.4	4.6 ± 3.2	6.8 ± 4.4	13.1 ± 2.5
Yes	30.0 ± 4.9	13.1 ± 3.9	4.6 ± 3.3	7.5 ± 5.2	13.0 ± 2.8
Parents education: Cohen d (p-value)	0.33 (< 0.001)	0.23 (< 0.001)	0.14 (0.052)	0.22 (0.002)	0.15 (0.034)
Both parents ≤high school	30.1 ± 4.7	13.1 ± 3.3	5.0 ± 3.4	7.5 ± 4.9	12.9 ± 2.7
At least one ≥post-secondary	31.2 ± 4.1	13.9 ± 3.2	4.6 ± 3.2	6.5 ± 4.2	13.3 ± 2.4
Main language at home: largest Cohen d (p-value)	0.56[a] (< 0.001)	0.09[b] (0.316)	0.07[a] (0.868)	0.42[a] (0.018)	0.35[a] (0.050)
French	30.8 ± 4.5	13.5 ± 3.3	4.6 ± 3.1	6.8 ± 4.4	13.2 ± 2.5
French and other	30.2 ± 4.5	13.2 ± 3.7	4.7 ± 3.3	6.9 ± 4.6	13.0 ± 2.6
Other	28.1 ± 5.2	13.3 ± 3.4	4.8 ± 3.6	8.7 ± 4.6	12.3 ± 3.1
Chronic disease: Cohen d (p-value)	0.19 (0.006)	0.07 (0.284)	0.11 (0.116)	0.00 (0.961)	0.00 (0.983)
No	30.4 ± 4.5	13.4 ± 3.4	4.6 ± 3.2	6.9 ± 4.5	13.1 ± 2.6
Yes	31.2 ± 4.6	13.6 ± 3.5	4.9 ± 3.2	6.9 ± 4.4	13.1 ± 2.5
Weight classification**: largest Cohen d (p-value)	0.30[c] (0.005)	0.11[d] (0.513)	0.16[b] (0.668)	0.15[b] (0.131)	0.18[b] (0.777)
Under weight	30.7 ± 4.7	13.7 ± 3.4	4.6 ± 3.1	7.3 ± 4.4	13.1 ± 2.5
Normal weight	30.8 ± 4.4	13.5 ± 3.4	4.6 ± 3.2	6.7 ± 4.5	13.1 ± 2.5
Overweight	29.6 ± 4.8	13.1 ± 3.7	4.8 ± 3.5	7.5 ± 5.1	13.1 ± 2.7
Obesity	29.3 ± 3.9	13.1 ± 2.9	5.1 ± 3.0	7.6 ± 4.3	12.7 ± 2.8

Statistical tests are Student or anova as appropriate. Cohen'd is corrected for uneven group size if necessary. * Higher scores mean lower HL. **Adapted to sex and age, according to the International Obesity Task Force. Largest Cohen's d between: [a] "French" and "Other", [b] "French" and "French and other", [c] "Normal weight" and "Obesity", [d] "Under weight" and "Obesity".

4. Discussion and conclusion

4.1. Discussion

This study is, to our knowledge, the first one to assess simultaneously the psychometric properties of three recently developed HL scales on the same large sample of adolescents from various social backgrounds. This design of the study allowed to draw the following key results: First, these three scales showed measurement invariance across adolescence from 13 years-old and measurement invariance across sex; Second, convergent validity is low, which means that the HL-related constructs measured by these three scales are different; Third, among the three HL scales, the HLS-EU-Q16 is the one of which the psychometric properties indicate that it is less appropriate for use amongst adolescents (acceptable fit of the CFA model compared to good fit for HAS-A, results rarely in agreement with a priori hypotheses compared to always in agreement for HLSAC, undergraduate readability level according to the Flesch Readability Score compared to 7th grade for the HLSAC).

Measurement invariance is defined by Milsap as "a measuring device should function in the same way across varied conditions, so long as those varied conditions are irrelevant to the attribute being measured" [48]. It is recognized by the COSMIN initiative (COnsensus-based Standards for the selection of health Measurement Instruments) as an important psychometric property as it is closely related to construct validity [49]. Indeed, if a scale lacks of measurement invariance concerning a characteristic, it means that its factor structure is different according to this characteristic and thus, that the scale measures a different construct depending on this characteristic. Due to the developmental processes and changes of cognitive abilities that take place during the adolescence, measurement invariance is clearly important to check throughout the concerned age range whatever the construct being measured. Our study is the first to show that the HLSAC, the HAS-A and the HLS-EU-Q16 scales are invariant throughout adolescence (and also concerning sex) which means that they can be used longitudinally to assess change in HL level during adolescence.

However, when assessing convergent validity, it was shown that the scores on these three measures are weakly correlated. This lack of convergent validity is further confirmed by the absence of concordance (weighted kappa=0.24) between the two HL level classifications resulting from the use of the thresholds for HLSAC and HLS-EU-Q16. This means that while these instruments are all supposed to measure HL, they do not measure the same construct. It can be explained by the fact that the authors of each scale were guided by different HL definitions or conceptualizations, even if these three scales are supposed to encompass the three aspects (functional, interactive and critical) of HL. To develop the HAS-A, Manganello et al. explained that they used the Berkman's definition of HL ("the degree to which individuals can obtain, process, understand, and communicate about health-related information needed to make informed health decisions") [16,50]. The HL definition used by Sorensen et al. to develop the HLS-EU-Q16 is close to the Berkman's definition but "integrates the 'medical' conceptualization of HL with the broader 'public health' perspective of HL" with three domains of application: healthcare, disease prevention, health promotion [51]. Concerning the HLSAC, Paakkari et al. indicated that they were interested in HL conceptualized as a learning outcome and developed their tool with "the intention to move beyond HL assessment towards *how* HL can be developed further among the target group"[15]. It is important to be aware of these differences in order to decide which one of these three scales is most suitable for one' s purpose.

Finally, while it was hypothesized before the beginning of the data collection which characteristics of the adolescents would be associated with HL, the only measure for which these associations were found was the HLSAC (except for grade repetition maybe due to a lack of power). The effect sizes were small to medium which may indicate a lack of discriminating power for this scale. For the two other scales, the absence of the expected associations may be due to the fact that the measured construct is not the one we expected to measure, or to the presence of a ceiling effect, which could be the case for the HLS-EU-Q16. This effect may decrease the precision of the score, and thus the power to detect expected associations, as it means that the measure is not sufficiently discriminating for a large part of the sample.

This study has some limitations. First, the adolescents were asked to complete 3 HL tools, with a total of 41 items that closely resemble each other. This may have reduced their motivation and introduced a form of bias. However, there were very few missing answers to the items of the three instruments, with only 9 participants giving nonsensical answers and only 37 responding to less than half of the items, i.e. 3.1% of the whole sample. Second, we did not assess the sensitivity to change and the test-retest reliability of the measures, which are two important psychometric properties to assess. Further studies should evaluate these properties as they have never been assessed for the HLSAC and the HAS-A [14].

4.2. Conclusion

To conclude, the three scales exhibited acceptable to good structural validity and measurement invariance throughout adolescence and across sex. However, the Flesch readability score (7th grade), the internal consistency (Mac Donald omega =0.82) and the hypotheses testing are more in favour of the use of the HLSAC to assess HL during adolescence. On the other hand, the structural validity was slightly better for the HAS-A, which can be interesting as it may bring more analytic information due to the three measured dimensions. While it was not developed specifically for adolescents, the HLS-EU-Q16 could be chosen by some researchers as it could be useful to assess the change of HL level longitudinally throughout adolescence and adulthood. However, it should be considered that some adolescents may have problems understanding all the questions, as was noted during the focus groups and the pilot testing, and the readability Flesch score indicated that it is more suitable for undergraduate students. Moreover, for adolescents there also seems to be an important ceiling effect for this tool, which has also been observed in the adult population [17].

4.3. Practice implications

While adolescence is a period of opportunity for prevention and health promotion interventions, very few studies on HL have been conducted in adolescents, partly because of the lack of clear understanding on what is measured by the different existing HL measurement tools over the age span of 13–18 years. This study results clarify that the HL-related constructs measured by the HLSAC, the HAS-A and HLS-EU-Q16 scales are different (low convergent validity) while they all exhibited acceptable to good structural validity and measurement invariance throughout adolescence and across sex. Among the three HL scales, the HLS-EU-Q16 is the one of which the psychometric properties indicate that it is less appropriate for use amongst adolescents. As they are well suited and valid for adolescents from 13 to 19 years-old, the use of the HLSAC and HAS-A in clinical practice and research studies will help to focus on health literacy which is a critical factor for prevention and health promotion interventions in adolescence.

Funding

This work was supported by Santé Publique France, the National Public Health Agency [grant number RPG19021LLA 2018].

CRediT authorship contribution statement

Alexandra Rouquette: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Laurent Rigal**: Conceptualization, Methodology, Validation, Writing – review & editing. **Julien Mancini**: Validation, Writing – review & editing. **Francis Guillemin**: Validation, Writing – review & editing. **Stephan van den Broucke:** Validation, Writing – review & editing. **Cécile Allaire**: Funding acquisition, Resources, Validation, Writing – review & editing. **Sylvie Azogui-Levy**: Investigation, Methodology, Visualization, Writing – review & editing. **Virginie Ringa**: Conceptualization, Funding acquisition, Supervision, Validation, Writing – review & editing. **Christine Hassler**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Project administration, Resources, Validation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

Acknowledgments

The authors would like to thank the adolescents who provided information for the survey, their families who allowed them to participate, and the educational staff who made it possible to organize the collection. The authors also want to thank the RéFLiS Network (Réseau Francophone de Littératie en Santé – Francophone Health Literacy Network - https://reflis.fr/) which provides a stimulating environment for exchange and reflection for Francophone researchers interested in health literacy, which the authors took advantage of to write this article.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.pec.2021.07.044.

References

[1] W.H.O. WHO, Health Literacy. The Solid Facts. 2013http://www.thehealthwell.info/search-results/health-literacy-solid-facts?&content=resource&member=572160&catalogue=none&collection=none&tokens_complete=true (accessed 1 June 2017).
[2] Osborne RH, Batterham RW, Elsworth GR, Hawkins M, Buchbinder R. The grounded psychometric development and initial validation of the Health Literacy Questionnaire (HLQ). BMC Public Health 2013;13:658. https://doi.org/10.1186/1471-2458-13-658
[3] Sørensen K, Van den Broucke S, Pelikan JM, Fullam J, Doyle G, Slonska Z, et al. Measuring health literacy in populations: illuminating the design and development process of the European Health Literacy Survey Questionnaire (HLS-EU-Q). BMC Public Health 2013;13:948. https://doi.org/10.1186/1471-2458-13-948
[4] Nutbeam D. The evolving concept of health literacy. Soc Sci Med 2008;67:2072–8. https://doi.org/10.1016/j.socscimed.2008.09.050
[5] Cho YI, Lee S-YD, Arozullah AM, Crittenden KS. Effects of health literacy on health status and health service utilization amongst the elderly. Soc Sci Med 2008;66:1809–16. https://doi.org/10.1016/j.socscimed.2008.01.003
[6] Mantwill S, Schulz P. Low health literacy associated with higher medication costs in patients with type 2 diabetes mellitus: Evidence from matched survey and health insurance data. Patient Educ Couns 2015http://europepmc.org/abstract/med/26198546 (Accessed 1 June 2017).
[7] Berkman ND, Sheridan SL, Donahue KE, Halpern DJ, Crotty K. Low health literacy and health outcomes: an updated systematic review. Ann Intern Med 2011;155:97–107. https://doi.org/10.7326/0003-4819-155-2-201107190-00005
[8] Bostock S, Steptoe A. Association between low functional health literacy and mortality in older adults: longitudinal cohort study. BMJ (Clin Res Ed) 2012;344:1602https://doi.org/10.1136/bmj.e1602
[9] WHO. Shanghai Declaration on promoting health in the 2030 Agenda for Sustainable Development. Health Promotion International. Geneva, Switzerland: WHO,; 2017. p. 7–8 (Accessed 2 August 2020). https://www.who.int/publications-detail-redirect/WHO-NMH-PND-17.5.
[10] Borzekowski DL. Considering children and health literacy: a theoretical approach. Pediatrics 2009;124(Suppl 3):S282–8. https://doi.org/10.1542/peds.2009-1162D
[11] Arnett JJ. Adolescence and Emerging Adulthood: A Cultural Approach. Third ed. Upper Saddle River, NJ: Prentice Hall,; 2006.
[12] Manganello J, Shone L. Health Literacy: Research FACTS and Findings. ACT for Youth Center of Excellence Ithaca; 2013.
[13] Santoro K, Speedling C. The case for investing in youth health literacy: One step on the path to achieving health equity for adolescents. NIHCM Issue Brief 2011:1–15.
[14] Guo S, Armstrong R, Waters E, Sathish T, Alif SM, Browne GR, et al. Quality of health literacy instruments used in children and adolescents: a systematic review. BMJ Open 2018;8:020080https://doi.org/10.1136/bmjopen-2017-020080
[15] Paakkari O, Torppa M, Kannas L, Paakkari L. Subjective health literacy: development of a brief instrument for school-aged children. Scand J Public Health 2016;44:751–7. https://doi.org/10.2307/48512708
[16] Manganello J, DeVellis RF, Davis TC, Schottler-Thal C. Development of the health literacy assessment scale for adolescents (HAS-A). J Commun Healthc 2015;8:172–84. https://doi.org/10.1179/1753807615Y.0000000016
[17] Rouquette A, Nadot T, Labitrie P, Van den Broucke S, Mancini J, Rigal L, Ringa V. Validity and measurement invariance across sex, age, and education level of the French short versions of the European Health Literacy Survey Questionnaire. PLOS ONE 2018;13:0208091https://doi.org/10.1371/journal.pone.0208091
[18] Jackson AD, Kirwan L, Gibney S, Jeleniewska P, Fletcher G, Doyle G. Associations between health literacy and patient outcomes in adolescents and young adults with cystic fibrosis. Eur J Public Health 2020;30:112–8. https://doi.org/10.1093/eurpub/ckz148
[19] Pelikan J, Ganahl K, Van den Broucke S, Sørensen K. Measuring Health Literacy in Europe: Introducing the European Health Literacy Survey Questionnaire (HLS-EU-Q). In: Bauer U, Okan O, Pinheiro P, Levin-Zamir D, Sørensen K, editors. International Handbook of Health Literacy: Research, Practice and Policy across the Lifespan. Bristol: Policy Press; 2018.
[20] Röthlin F, Pelikan J, Ganahl K. Die Gesundheitskompetenz von 15-jährigen Jugendlichen in Österreich. Abschlussbericht der österreichischen Gesundheitskompetenz Jugendstudie im Auftrag des Hauptverbands der österreichischen Sozialversicherungsträger (HVSV). Wien, Austria: Ludwig Boltzmann Institut Health Promotion Research (LBIHPR); 2013.
[21] Domanska OM, Firnges C, Bollweg TM, Sørensen K, Holmberg C, Jordan S. Do adolescents understand the items of the European Health Literacy Survey Questionnaire (HLS-EU-Q47) - German version? Findings from cognitive interviews of the project "measurement of health literacy among adolescents" (MOHLAA) in Germany. Arch Public Health 2018;76:46. https://doi.org/10.1186/s13690-018-0276-2
[22] Paakkari O, Torppa M, Villberg J, Kannas L, Paakkari L. Subjective health literacy among school-aged children. Health Educ 2018;118:182–95. https://doi.org/10.1108/HE-02-2017-0014
[23] J.M. Pelikan, Measuring comprehensive health literacy in general populations – The HLS-EU Instrument, 2014. https://www.google.fr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwi1vZr434rRAhXC7RQKHVsqCrYQFggkMAE&url=http%3A%2F%2Fwww.ahla-asia.org%2Fincludes%2Ffile_down.php%3Ffile%3D.%252Fpublic%252Fperd%252Fchinese%252FPelikan-Taipeh%2BHLS-EU-10–14%2Bfinfin.pdf&usg=AFQjCNEF65mwRACr88iBBMkretzecMQ0RQ&sig2=SjqT7K5zuOGmAfufflW6iA&cad=rja.
[24] Pelikan J, Ganahl K. Measuring health literacy in general populations: primary findings from the hls-eu consortium's health literacy assessment effort. Stud Health Technol Inform 2017;240:34–59.
[25] Epstein J, Santo RM, Guillemin F. A review of guidelines for cross-cultural adaptation of questionnaires could not bring out a consensus. J Clin Epidemiol 2015;68:435–41. https://doi.org/10.1016/j.jclinepi.2014.11.021
[26] Ménoni V, Lucas N, Leforestier JF, Dimet J, Doz F, Chatellier G, et al. The readability of information and consent forms in clinical research in France. PLOS ONE 2010;5:10576https://doi.org/10.1371/journal.pone.0010576
[27] Rouquette A, Falissard B. Sample size requirements for the internal validation of psychiatric scales. Int J Methods Psychiatr Res 2011;20:235–49.
[28] Terwee CB, Bot SD, de Boer MR, van der Windt DA, Knol DL, Dekker J, Bouter LM, de Vet HC. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol 2007;60:34–42. https://doi.org/10.1016/j.jclinepi.2006.03.012
[29] de Vet HCW, Terwee CB, Mokkink LB, Knol DL. Measurement in Medicine: A Practical Guide. Cambridge University Press; 2011http://books.google.fr/books?id=_OcdeTg9i28C.
[30] Muthén LK, Muthén BO. (1998-2012). MPlus. Statistical Analysis With Latent Variables. User's Guide. Seventh ed. 2012.
[31] Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Model 1999;6:1–55. https://doi.org/10.1080/10705519909540118
[32] Brown TA. Confirmatory factor analysis for applied research. New York: The Guilford Press; 2006.
[33] Kline RB. Principles and Practice of Structural Equation Modeling. Third ed. New York: The Guilford Press; 2010.
[34] Chen FF. Sensitivity of goodness of fit indexes to lack of measurement invariance. Struct Equ Model 2007;14:464–504. https://doi.org/10.1080/10705510701301834
[35] Cheung GW, Rensvold RB. Evaluating goodness-of-fit indexes for testing measurement invariance. Struct Equ Model 2002;9:233–55. https://doi.org/10.1207/S15328007SEM0902_5

[36] Watkins MW. The reliability of multidimensional neuropsychological measures: from alpha to omega. Clin Neuropsychol 2017;31:1113–26. https://doi.org/10.1080/13854046.2017.1317364
[37] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74. https://doi.org/10.2307/2529310
[38] Feinberg I, Frijters J, Johnson-Lawrence V, Greenberg D, Nightingale E, Moodie C. Examining associations between health information seeking behavior and adult education status in the u.s.: an analysis of the 2012 PIAAC Data. PLOS ONE 2016;11:0148751https://doi.org/10.1371/journal.pone.0148751
[39] Asokan GV1*, Yusuf MYA, Kirubakaran R, Albadwi AMM, Saad AE, Mjahed AHS, et al. Levels and determinants of health literacy in bahrain's community context. Oman Med J 2020;35:e195https://doi.org/10.5001/omj.2020.88
[40] Guo S, Yu X, Davis E, Armstrong R, Riggs E, Naccarella L. Adolescent health literacy in beijing and melbourne: a cross-cultural comparison. Int J Environ Res Public Health 2020;17:1242. https://doi.org/10.3390/ijerph17041242
[41] Rababah JA, Al-Hammouri MM, Drew BL, Aldalaykeh M. Health literacy: exploring disparities among college students. BMC Public Health 2019;19:1401. https://doi.org/10.1186/s12889-019-7781-2
[42] Beauchamp A, Buchbinder R, Dodson S, Batterham RW, Elsworth GR, McPhee C, et al. Distribution of health literacy strengths and weaknesses across socio-demographic groups: a cross-sectional survey using the Health Literacy Questionnaire (HLQ). BMC Public Health 2015;15:678. https://doi.org/10.1186/s12889-015-2056-z
[43] Deliens T, Clarys P, De Bourdeaudhuij I, Deforche B. Weight, socio-demographics, and health behaviour related correlates of academic performance in first year university students. Nutr J 2013;12:162. https://doi.org/10.1186/1475-2891-12-162
[44] Rosnow RL, Rosenthal R, Rubin DB. Contrasts and correlations in effect-size estimation. Psychol Sci 2000;11:446–53. https://doi.org/10.1111/1467-9280.00287
[45] L.P. StataCorp, Stata Statistical Software: Release 14, StataCorp, L.P., College Station, TX, 2015.
[46] Guignon N, Delmas M, Fonteneau L. [In 2017, teenagers in better physical health but more often overweight]. DREES, Etudes Résultats 2019;1122:1–6.
[47] Pacoricona A, Sentenac M, Godeau E. The health of middle school students in France / 2014. French data from the international survey Health Behaviour in school-aged children (HBSC)]. Handicap et maladie chronique. St Publique Fr 2016:4.
[48] Millsap RE. Statistical Approaches to Measurement Invariance. First ed. New York: Routledge,; 2011.
[49] Mokkink LB, Terwee CB, Patrick DL, Alonso J, Stratford PW, Knol DL, Bouter LM, de Vet HCW. The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. J Clin Epidemiol 2010;63:737–45. https://doi.org/10.1016/j.jclinepi.2010.02.006
[50] Berkman ND, Davis TC, McCormack L. Health literacy: what is it? J Health Commun 2010;15(Suppl 2):9–19. https://doi.org/10.1080/10810730.2010.499985
[51] Sørensen K, Van den Broucke S, Fullam J, Doyle G, Pelikan J, Slonska Z, et al. Health literacy and public health: A systematic review and integration of definitions and models. BMC Public Health 2012;12:80. https://doi.org/10.1186/1471-2458-12-80