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Toward a representative assessment of competencies for a healthy, physically active lifestyle in the German population: development and validation of a short version of the physical activity-related health competence questionnaire (PAHCO_12)

Introduction

Physical activity in Germany

Physical activity constitutes one of the behaviors that individuals can deliberately influence and that exerts positive effects on multiple aspects of health (Li et al., 2018; Warburton & Bredin, 2017). Unfortunately, the global percentage of individuals meeting established physical activity guidelines (e.g., of at least 150 min of moderate-to-vigorous intensity per week (Bull et al., 2020; Rütten et al., 2016)), is relatively low and has raised concerns among scientists and policymakers (Ding et al., 2020; Guthold, Stevens, Riley, & Bull, 2018; Santos, Willumsen, Meheus, Ilbawi, & Bull, 2023). Specifically, epidemiological data underscored that the physical activity behavior in Germany does not positively differ from the international situation (Guthold et al., 2018).

More than half of women (57.4%) and men (51.2%) do not meet the recommendations for aerobic physical activity, and around four in five women (79.5%) as well as three in four men (75.3%) do not meet the recommendations for both aerobic physical activity and muscle-strengthening activities (Finger, Mensink, Lange, & Manz, 2017). In recent years, knowledge about the behavioral patterns of specific age groups and populations has improved substantially, also nourished by representative surveys and large-scale studies with objective physical activity measurements (Leitzmann et al., 2020; Richter et al., 2021; Sudeck et al., 2021). Fueled by the increasing body of evidence about physical inactivity, it is necessary to invest efforts into the effective promotion of physical activity on both the national and the international level (Rütten et al., 2016; World Health Organization, 2018).

However, to inform interventions, researchers are advised to accumulate knowledge about the determinants of physical activity. Ideally, a theoretical approach is chosen that not only explains short-term physical activity (for an overview of theories, see Biddle, Gorely, Faulkner, & Mutrie, 2023; Rhodes, McEwan, & Rebar, 2019) but that considers the adoption or maintenance of a physically active lifestyle as a long-term or sustainable process (Dunton et al., 2022). Therefore, it appears necessary for researchers and practitioners to comprehend physical activity as a behavior habit that must be "learned". By drawing on conceptions from educational sciences, it makes sense to define "competencies" (Kurz & Gogoll, 2010; Weinert, 2001) as a key prerequisite to lead a physically active lifestyle. The World Health Organization indirectly confirms this claim by repeatedly sug-
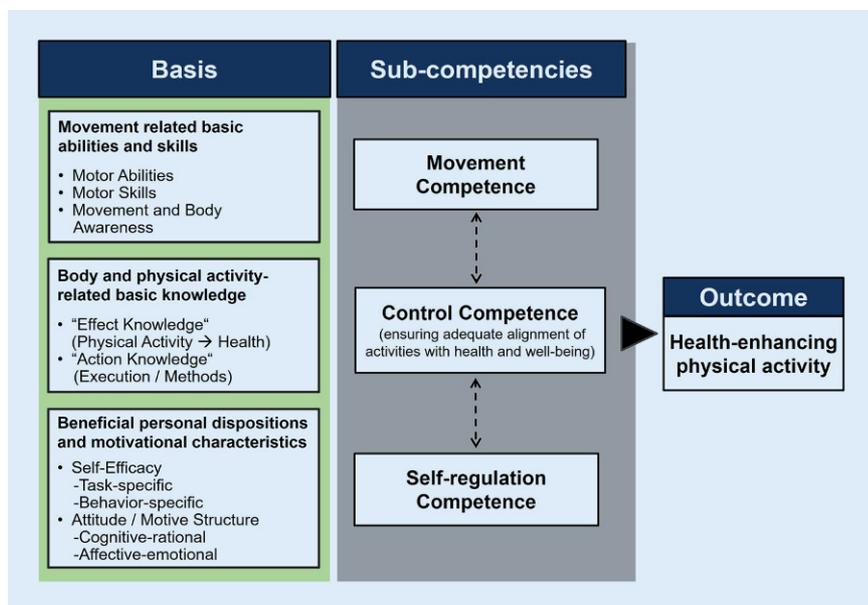
Fig. 1 ▲ The physical activity-related health competence (PAHCO) model. (Sudeck & Pfeifer, 2016)

gesting to address "competencies" as well as health literacy and physical literacy within its Global Action Plan on Physical Activity 2018–2030 (World Health Organization, 2018). Empirical studies indicate associations between health literacy and physical activity (Buja et al., 2020; Jordan & Hoebel, 2015). Given the need to better comprehend the determinants that lead to healthy, physically active lifestyles, specific concepts and tools at the interface of health literacy and physical activity appear relevant. One of the theoretical approaches that builds on such competencies while integrating quantitative and qualitative aspects for health-enhancing physical activity is the physical activity-related health competence model, which conceptually links ideas of health literacy and physical literacy research (Carl, Sudeck, & Pfeifer, 2020a; Haible et al., 2020).

The physical activity-related health competence (PAHCO) model

The physical activity-related health competence (PAHCO) model specifies three sub-competencies to follow a healthy, physically active lifestyle (Carl et al., 2020a; Sudeck, Rosenstiel, Carl, & Pfeifer, 2022): movement competence, control competence, and self-regulation competence (▶ Fig. 1). *Movement compe-*

tence bundles all the directly movement-related qualities (e.g., motor requirements, fitness aspects) to participate in planned exercise and to master activities of daily living (e.g., cycling, shopping). *Control competence* serves as the qualitative component that aligns all physical activities with individuals' health, from both a physical (e.g., application of appropriate training loads) and a psychosocial standpoint (e.g., stress and affect regulation through physical activity). *Self-regulation competence* describes the motivational–volitional requirements to ensure the regularity of physical activity (frequent initiation, perseverance of a session). In line with general assumptions underlying the educational conceptualizations of "competence", these sub-competencies result from the convergence of "to know", "to can", and "to want" (Töpfer & Sygusch, 2014; Weinert, 2001). Accordingly, the sub-competencies represent integrated qualifications, composed of basic elements, that direct individuals toward goal-directed behavior (i.e., a healthy, physically active lifestyle). In this regard, movement competence is formed by the interplay of motor abilities, motor skills, body and movement awareness but also by, at least, a basic level of task-specific self-efficacy (to execute a movement). Moreover, the PAHCO model

posits that control competence builds on knowledge about physical activity and its effects as well as appropriate methods for exercising. Ideally, this knowledge is, in concrete situations, nourished by sensory information (ideally drawing on proficient body and movement awareness) and critical reflection processes as the basis of decisions for or against certain physical activities. Finally, self-regulation competence results from individual motive constellations and self-efficacy as motivational sources, complemented through skills of behavioral control which help bridge intention–behavior gaps or maintain effort during planned action (Sudeck & Pfeifer, 2016).

In recent research, scholars have increasingly recognized the value of this framework by employing the PAHCO model among different target groups along the health promotion and rehabilitation spectrum, including children (Lindemann, Gröben, & Braksiek, 2023; Volk et al., 2021), apprentices (Grüne, Popp, Carl, Semrau, & Pfeifer, 2022), graduate students (Carl, Sudeck, & Pfeifer, 2020b), office workers (Blaschke, Carl, Pelster, & Mess, 2023), adults (Holler, Carl, v. Poppel, & Jaunig, 2023), as well as people with non-communicable diseases (Durst, Roesel, Sudeck, Sassenberg, & Krauß, 2020; Schmid et al., 2023). However, all these studies were conducted on the level of segmented populations and, therefore, lack generalizability and representativity to inform policy on the promotion of a physically active lifestyle in the general population. Therefore, adopting a public health perspective, initiatives are needed that allow stakeholders to monitor PAHCO in the German population. More specifically, detailed knowledge about the "competence" of a society to lead physically active lifestyles has the potential to inform a multitude of future interventions in the field of physical activity and health in Germany.

Goals and research questions

The goal of the present study was to develop an assessment instrument on the basis of the PAHCO model that can be integrated within larger telephone-

based surveys of the Robert Koch Institute (RKI) for representative assessments in the adult population. Accordingly, the *first research question* takes a processual perspective with a methodological focus by asking: how is a short version of the PAHCO questionnaire constructed that adequately meets the basic theoretical assumptions of the PAHCO model, on the one hand, and is valid and economic for an assessment via telephone, on the other? Subsequently, the goal was to evaluate the psychometric quality and validity (i.e., factorial validity, criterion validity) of this short version of the questionnaire. Accordingly, the *second research question* takes a technical perspective by asking: does the short version of the PAHCO questionnaire meet methodological standards to supply valid information about the level of PAHCO in the population of Germany?

Methods

Study design

The Robert Koch Institute (RKI) is Germany's national Public Health Institute and the central institution of the Federal Government in the field of surveillance, control, and prevention of diseases. The RKI performs regular representative surveys within the adult population titled "German Health Update" (GEDA) [in German: „Gesundheit in Deutschland aktuell"]. It is a telephone-based survey using a random sample of the German-speaking population aged 18 and older in private households that can be reached via landline or mobile phone (for details on the methodology, see Allen et al., 2021; Damerow, Born, Walther, & Wetzstein, submitted). Within the 2023 wave, specific attention has been placed on aspects of physical activity (assessment period January–Mai 2023) with a potential sample size of around 4000 adults aged 18 years and older. In accordance with the increasing importance of the health literacy concept in Germany (Jordan & Hoebel, 2015; Messer, Dadaczynski, & Okan, 2022; Schaeffer, Hurrelmann, Bauer, Kolpatzik, & Altiner, 2018), the RKI aimed to integrate questions that operationalize health-related

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Abstract

Representative studies assessing behavior-oriented determinants for physically active lifestyles in the German adult population are lacking due to the absence of validated assessment instruments. Drawing on the physical activity-related health competence (PAHCO) model, the goal of the present study was to develop and evaluate a short version of PAHCO differentiating between the three sub-competencies 'movement competence', 'control competence', and 'self-regulation competence'. In the first step, we reduced the number of items from existing PAHCO-related questionnaires, while adjusting them for a telephone survey mode. In the second step, we validated this 12-item version with $N = 3986$ adults between 18 and 97 years (57.0 ± 18.2 years; 52.0% male) within the representative survey "German health Update" (GEDA 2023). We also gathered information about participants' age, gender, education, leisure-time physical activity, and self-reported health. The psychometric analyses revealed satisfactory item statistics. Confirmatory factor analyses suggested a model variant in which two items showed theory-conform parallel loadings on a second sub-competence (comparative fit index [CFI] = 0.924, root mean square error of approximation [RMSEA] = 0.073, standardized root mean square residual [SRMR] = 0.044). The latent sub-competencies were significantly related to physical activity ($0.20 \le \beta \le 0.27$) and health ($0.50 \le \beta \le 0.65$), thus indicating criterion validity. The factor structure turned out to be invariant across age, gender, and educational levels. In summary, this study gained initial insights about the reliability and validity of a 12-item version of the PAHCO questionnaire. We recommend the instrument for use within representative surveys, for initial screening, the reporting of descriptive trends, or secondary outcomes of a trial.

Keywords

Exercise · Health literacy · Physical activity · Physical literacy · Validity

requirements for active lifestyles, theoretically localized at the interface between health literacy and physical literacy research (Carl et al., 2020a).

Item selection and adjustment process

The PAHCO model conceptually addressed this interface between health literacy and physical literacy, while also providing a standardized assessment instrument with 42 items (Carl et al., 2020b). This specific instrument included ten different scales that could be empirically assigned to the three sub-competencies of PAHCO: movement competence with five scales ($n = 21$ items), control competence with three scales ($n = 15$ items), and self-regulation competence with four scales ($n = 14$ items). The final solution of this questionnaire considered two theory-compatible parallel loadings, meaning that two scales (body and movement awareness; task-specific self-efficacy) and ten items, respectively, loaded on two sub-competences (which explains why simply summing up the values results in a higher number of scales and items). In addition, and in line with initial PAHCO descriptions (Sudeck & Pfeifer, 2016), we considered the measurement of motivational competence in exercise and sport ($n = 4$ items) (Schorno, Sudeck, Gut, Conzelmann, & Schmid, 2021) to strengthen competence orientation in the operationalization of self-regulation competence.

This total set of 46 items (the 42 items of the PAHCO long version plus the four items of the motivational competence in exercise and sport questionnaire) marked the starting point for the selection process. In accordance with the goal to not only reduce the number of

items but also harmonize the entire assessment with a telephone-based mode and a population survey, we organized the adjustment through two complementary expertise perspectives: (a) both experts with an academic background in sport science as well as health-enhancing physical activity and experts with an academic background in public health and health literacy for ensuring theoretical–thematic compatibility, and (b) experts with an academic and professional background in the development of questionnaires as well as population-based (especially telephone-based) surveys for ensuring organizational–methodological compatibility. From a theoretical–thematic perspective, the claim was to maintain the conceptual breadth of PAHCO while not giving up basic psychometric claims or the factorial structure (bandwidth-fidelity dilemma; see Ones & Viswesvaran, 1996). From an organizational–methodological perspective, the entire questionnaire part on physical activity (as one topic among different health behaviors) should not exceed eight minutes in total. It should consist of clear, selective, and unambiguous questions, which should be easily understood via telephone across the educational spectrum to ensure representativity at the population level. In this regard, the selection and adjustment process was informed by the GEDA standards for telephone-based assessments (Allen et al., 2021). The item construction adhered to a pragmatic strategy with successive alterations between both expert groups. More specifically, the expertise group that has undertaken the development of the long version of the PAHCO questionnaire has generated an initial pool of 16 items based on theoretical reflections ("marker items" with a good, broad representation of a construct) and empirical experiences from former studies (e.g., via item reliabilities, item difficulties, sensitivity of change, theoretical "marker"). Subsequently, the expertise group at the RKI (SJ, AL, MB, KM, and OD) identified items whether items could be adopted without change, had to be adjusted, omitted, or replaced with alternative items from the long version. The expertise group, in turn, sent

their suggestions and material back to the first team and the alternating proceeding was maintained until both expertise groups recognized quality saturation.

External variables and sociodemographic information

The survey has included one question about the volume of leisure-time physical activity behavior from the European Health Interview Survey—Physical Activity Questionnaire (EHIS-PAQ; Finger et al., 2015): "How many total hours and minutes do you spend in a usual week with sport, fitness, or physical activity during leisure-time?" [German: "Wie viele Stunden und Minuten verbringen Sie insgesamt in einer typischen Woche mit Sport, Fitness oder körperlicher Aktivität in der Freizeit?"]. Afterwards, the interviewer noted participants' free specification. The self-reported health status was assessed with one item within the Minimum European Health Module (Eurostat, 2013): "Now I want to ask you questions about your health. How is your health status in general?" [German: "Ich möchte Ihnen jetzt Fragen zu Ihrer Gesundheit stellen. Wie ist Ihr Gesundheitszustand im Allgemeinen?"]. The answer options were "very good", "good", "fair", "poor", and "very poor" [German: "sehr gut", "gut", "mittelmäßig", "schlecht", "sehr schlecht"].

We determined participants' age based on the self-reported birth year and month. Interviews were discontinued and participants excluded if the calculated age was under 18 years. Interviewees were asked about their gender identity: "Since not all individuals feel that they belong to their registered gender: Which gender do you feel you belong to?" [German: "Da sich nicht alle Menschen ihrem eingetragenen Geschlecht zugehörig fühlen: Welchem Geschlecht fühlen Sie sich zugehörig?"]. The participants could choose between "male", "female", and "others, namely [blank]". Finally, we extracted education with the CASMIN classification (Brauns, Scherer, & Steinmann, 2003; Schneider, 2015) introducing with the question: "Which highest vocational degree of education or studies do you have?"

[German: "Welchen höchsten beruflichen Ausbildungs- oder Hochschul-/ Fachhochschulabschluss haben Sie?"]. The interviewees could choose between ten different options, with the instruction to find an equivalent if qualifications were obtained in other countries.

Overall validation strategy

After the identification of appropriate items for the short version of PAHCO, we undertook psychometric validation with an unweighted dataset involving the following successive stages (as in line with: Bühner, 2021): (1) explorative item analysis; (2) examination of factorial validity and reliability via confirmatory factor analysis (CFA); (3) analysis of associations with indicators of physical activity and health (criterion validity) using structural equation modeling (SEM); and (4) inspection of measurement invariance in regard to age, gender, and education.

Statistics

After the item selection and adjustment, we conducted all statistical analyses (steps 1–4) using the software R (version 4.3.0, R Foundation for Statistical Computing, Vienna, Austria) with the Lavaan package (version 0.6–15; Rosseel, 2021). Within the scope of *explorative item analysis* (step 1), we examined basic descriptive statistics (mean value and item difficulty, standard deviation, skewness, and kurtosis). In this context, we explicitly permitted various item difficulties (ID) to enable potential differentiations in more extreme ranges (i.e., $0.05 < ID \leq 0.20$ and $0.80 \geq ID > 0.95$) but tolerated this for only one item per scale. Furthermore, we inspected McDonalds's ω (internal consistency) for each scale (Zinbarg, Revelle, Yovel, & Li, 2005) as well as part-whole correlation coefficients for each item. Shapiro–Wilk tests delivered information about potential deviations from normal distribution (Razali & Wah, 2011).

For the investigation of the *factorial structure* (step 2), we specified CFA models with robust maximum likelihood estimators (MLRs) to counteract

violations against multivariate normality. In terms of the global model fit, we adhered to the recommendations by Hu and Bentler (1998) requesting the report of the comparative fit index (CFI) as a goodness-of-fit indictor as well as the standardized root mean square residual (SRMR) and the root mean square error of approximation (RMSEA) as a badness-of-fit indices. For evaluating the magnitude of these coefficients, we followed common guidelines indicating good (RMSEA ≤ 0.05, SRMR ≤ 0.05, CFI ≥ 0.95) or acceptable/satisfactory (RMSEA ≤ 0.08, SRMR ≤ 0.10, CFI ≥ 0.90) model fits (Schermelleh-Engel, Moosbrugger, & Müller, 2003; Weiber & Mühlhaus, 2015). The participants could choose to not provide information on a single question [German: "keine Angabe"] or answer with "I don't know" [German: "Ich weiß es nicht"]. In all CFA and SEM procedures, we technically handled such missing values with full information maximum likelihood (FIML) imputation techniques. In line with the validation procedure as undertaken with the long version of the PAHCO questionnaire (Carl et al., 2020b), we calculated two different model variants: one model in which all items just loaded on one sub-competence (*simple loading structure*) and one model with theory-compatible parallel loadings (*parallel loading structure*) of two items. The only difference between both model variants is that the parallel loading structure considered body and movement awareness operationalizations as being assigned to both control competence and movement competence as well as task-specific self-efficacy operationalizations as being assigned to both self-regulation competence and movement competence (for previous descriptions of the corresponding PAHCO foundations, see Sect. "The physical activity-related health competence (PAHCO) model", and for previous descriptions of the same validation approach in the original long version of the questionnaire, see Sect. "Item selection and adjustment process" within this article). These models were contrasted with Akaike's (AIC) and Bayes' (BIC) information criteria as well as the Satorra–Bentler scaled chi² difference test (ΔSB-χ²) as an inferential statistical procedure for nested model comparisons. In a next step, we extended the models as mentioned above to SEM by examining associations of the sub-competencies with leisure-time physical activity and the self-reported health status (*criterion validity*) as theory-conform external variables of metric character (step 3). In this context, we explored potential differences in the magnitude of the associations after applying logarithm-based Fisher's z transformations. Moreover, we investigated whether there are statistical arguments to compare levels of PAHCO between relevant subgroups (step 4). We undertook classifications that still ensured a power of $n ≥ 300$ for each class. In this context, we contrasted gender (male and female), formed five different age groups (18–35 years, 35–50 years, 51–65 years, 66–80 years, ≥ 80 years), and used the categorization of CASMIN into three education groups (low, medium, high). Technically, we submitted the short version of PAHCO to an examination of measurement invariance via multigroup comparisons. More specifically, we successively restricted the factor loadings (metric invariance), the intercepts (scalar invariance), and the residuals (strict invariance). We maintained the corresponding next invariance level if the changes in the fit coefficients did not surpass the suggested levels (Chen, 2007): ΔCFI ≤ –0.01, ΔRMSEA ≥ 0.015, and ΔSRMR ≥ 0.03 (for metric invariance) and ΔSRMR ≥ 0.01 (for scalar and strict invariance), respectively. To undertake comparisons with this instrument in the future, we had to record at least scalar invariance within this study (Van de Schoot, Lugtig, & Hox, 2012). Finally, we formed a manifest overall PAHCO score with all items (PAHCO_12), if approved by scale reliability (again via McDonald's ω) and criterion validity reflecting bivariate associations with leisure-time physical activity and the self-reported health status.

Results

Initial item pool

From an organizational–methodological perspective, the discussions revealed that we could only reserve 10–12 questions on PAHCO for the telephone survey due to a time limit for the overall interview. Concurrently, the thematic conceptualization of the short version of the PAHCO questionnaire was driven by the following claims: (a) the operationalization of movement competence should still be guided by differentiations into whether demands rather referred to endurance, strength, balance, or sensory information (i.e., body awareness); (b) in terms of control competence, we were interested in distinguishing between individual's alignment with physical health, on the one hand, and with psychological well-being, on the other; (c) self-regulation competence, in turn, should cover both motivational and volitional aspects. The maximum number of items in the survey implied that most of these differentiated aspects could only be represented by a single item. In summary, the selection and adjustment of single items were based on a mixture of psychometric findings from previous projects (item difficulty, factor loadings) as well as evaluations of basic comprehensibility among the general populations. Finally, we generated a total of 12 items, which all have to be answered on a five-point Likert scale. The questions were introduced with "Now, its's all about exercise. Which answer applies best to you?" [German: "Nun geht es um das Thema Bewegung. Welche Antwort trifft am besten auf Sie zu?"]. The first two questions operationalizing the manageability of endurance and strength demands (as part of movement competence) ranged from 1 = "I can do this without any problems" [German: "Ich kann dies ohne Probleme"] to 5 = "I cannot do this" [German: "Ich kann dies nicht"], and required subsequent inverting. All other questions ($n = 10$) had answering options from 1 = "does not apply" [German: "trifft nicht zu"] to 5 = "applies very much" [German: "trifft sehr zu"]. All items, answering options, and adjustments in comparison to

No.	Aspect	Attributable subcompetence[a]	Adjustments in comparison to the long version of PAHCO	Item in English language (translated)	Item in German language (as used in PAHCO_12)
1	Manageability of endurance demands	Movement competence	We replaced "running" with "jogging" to specify the movement	I can maintain a slightly exhausting physical activity, which makes me breathe a little faster (e.g., walking, slow jogging or cycling), for 30 min without a break	Ich kann eine etwas anstrengende körperliche Aktivität, bei der ich etwas schneller atmen muss, z. B. Gehen, langsames Joggen oder Radfahren, 30 min ohne Pause durchhalten
2	Manageability of strength demands	Movement competence	We replaced "15 kg" with "10 kg" to lower the physical challenges related to the characteristics of the population; accordingly, we adjusted the examples in the bracket Sentence order adjusted for better comprehensibility (examples at the end) We added an interviewer note to specify the item in case of a request	I can lift an object that is approx. 10 kg several floors upwards (e.g., full shopping bag, filled suitcase, small beverage crate) *[Interviewer note: In case of a request, please note: 3 floors]*	Ich kann einen ca. 10 kg schweren Gegenstand über mehrere Etagen hochtragen, z. B. volle Einkaufstasche, gefüllter Reisekoffer, kleine Getränkekiste *[Interviewerhinweis: Bei Nachfragen erfolgt der Hinweis: 3 Etagen]*
3	Manageability of balance demands	Movement competence	We adjusted the order of the sentence (i.e., "without losing the balance" was moved at the end of the sentence) for comprehensibility reasons	I can stand on one leg and reach for an object without losing balance	Ich kann auf einem Bein stehen, gleichzeitig nach einem Gegenstand greifen und verliere dabei nicht das Gleichgewicht
4	Movement and body awareness	Movement competence, control competence[a]	We slightly adjusted the construction of the sentence for comprehensibility reasons (previously without "helps me to master")	My body awareness helps me to master physically demanding situations well	Mein Körpergefühl hilft mir, körperlich fordernde Situationen gut zu bewältigen
5	Control of physical load	Control competence	We added an interviewer note to take into account that some people (on the population level) may have not exercised before	I am able to adjust my training effort well to my physical condition *[Interviewer note: The point is to choose the intensity of the training so that it suits your own physical condition. If people have never exercised before, please tick the answer category "does not apply"]*	Ich bin in der Lage, eine Trainingsbelastung gut auf meine körperlichen Voraussetzungen anzupassen *[Interviewerhinweis: Es geht darum, die Intensität des Trainings so zu wählen, dass sie zu den eigenen körperlichen Voraussetzungen passt. Wenn Personen noch nie trainiert haben, dann bitte die Antwortkategorie "trifft nicht zu" ankreuzen.]*
6	Control of physical load	Control competence	We added an interviewer note to take into account that some people (on the population level) may have not exercised before	I know how to use physical training to improve my endurance in the best possible way *[Interviewer note: If people have never exercised, please tick the answer category "does not apply"]*	Ich weiß, wie ich mit körperlichem Training meine Ausdauerleistung am besten steigern kann *[Interviewerhinweis: Wenn Personen noch nie trainiert haben, dann bitte die Antwortkategorie "trifft nicht zu" ankreuzen.]*
7	Control of physical load	Control competence	No changes undertaken	I know what to pay attention to in relation to my body in order to avoid excess load or insufficient load	Ich weiß, worauf ich bei meinem Körper achten muss, damit ich mich nicht über- oder unterfordere
8	Affect regulation	Control competence	In German, we removed the word "wieder" [translated: "again"] for comprehensibility reasons, which had no semantic and verbal consequence for the English version	I am well able to work off pent-up stress and inner tension through exercise	Ich kann aufgestauten Stress und innere Anspannung durch Bewegung gut abbauen

Table 1	(Continued)				
No.	Aspect	Attributable subcompetence[a]	Adjustments in comparison to the long version of PAHCO	Item in English language (translated)	Item in German language (as used in PAHCO_12)
9	Task-specific self-efficacy	Self-regulation competence, movement competence[a]	We added an interviewer note	I feel capable to perform physical activities that are challenging for me *[Interviewer note: This is about the physical activity/movement that you find demanding or challenging]*	Ich traue mir zu, für mich anspruchsvolle körperliche Aktivitäten durchzuführen *[Interviewerhinweis: Es geht um die körperliche Aktivität/Bewegung, die Sie für sich als anspruchsvoll empfinden oder die Sie vor eine Herausforderung stellt.]*
10	Self-control	Self-regulation competence	In German, we removed the word "zu wollen" [translated: "to want"] for comprehensibility reasons, which had no semantic and verbal consequence for the adaptation of the English version	When I decide to do more exercise, I am very disciplined in implementing this plan	Wenn ich mir vornehme, mich mehr zu bewegen, habe ich viel Disziplin bei der Umsetzung
11	Motivational competence for exercise and sport	Self-regulation competence	For comprehensibility reasons, we undertook slight adjustments in German for the last half clause, but this had no consequences for the English translation	I am very able to choose from a variety of exercise and sport activities the one that suits me best	Ich bin sehr gut in der Lage aus einer Vielfalt von Sport- und Bewegungsangeboten das auszuwählen, welches am besten zu mir passt
12	Self-control	Self-regulation competence	In German, we removed the word "körperlich" [translated: "physical"] in "körperlich-sportliche" for comprehensibility reasons, but it had no consequence for the English version (as it is covered by "exercise")	If I have planned to exercise, I generally follow through on this plan	Wenn ich eine sportliche Aktivität geplant habe, setze ich das in der Regel auch um

If two attributable sub-competences were mentioned per item, the second sub-competence was only included in the second model
[a]The present validation contrasted two theory-compatible models via confirmatory factor analysis (see Sect. "Overall validation strategy")

the long version of the PAHCO questionnaire can be retrieved from ◻ Table 1.

Participants

The present validations grounded on a total of $N = 3986$ individuals within this GEDA wave, corresponding to a telephone-based response rate of 19.4% (depending on the wave) in line with the response rate 3 of the American Association for Public Opinion Research (AAPOR) (Gramlich, Liebau, & Schunter, 2019). The participants were on average 57.04 ± 18.19 years old, and the self-reported health status was as follows: very poor 1.6%, poor 6.1%, fair 25.6%, good 49.5%, and very good 17.3%. Slightly more women (53.0%) than men (47.0%) were part of the validation. The participants reported the following educational levels: low 16.2%, moderate 45.1%, and high 38.8%.

Exploratory item analysis

The mean values of the 12 items ranged between 3.40 (item #8 on self-control) and 4.20 (item #1 on the manageability of endurance demands) along the 1–5 Likert scale, corresponding to item difficulties between 0.60 and 0.80 (◻ Table 2). In summary, all items were dominantly located in the upper half, yet still in an acceptable area (ID ≤ 0.80) of the scale. Although all 12 items deviated significantly from normal distribution ($0.70 \leq W \leq 0.90$, $p < 0.001$), we registered skewness values between −1.46 and −0.34 as well as kurtosis coefficients between −0.77 and 1.10. The proportion of missing values ranged between 0.4% (item #1 on the manageability of endurance demands) and 2.2% (item #4 on movement and body awareness).

Factorial validity

The model with the simple loading structure displayed an insufficient global fit

(CFI = 0.870, RMSEA = 0.094 [CI_{90} = 0.091–0.097], SRMR = 0.058, AIC = 135476, BIC = 135721), with only the SRMR coefficient showing an acceptable value (◻ Fig. 2a). When additionally considering theory-compatible parallel loadings of body and movement awareness as well as task-specific self-efficacy (◻ Fig. 2b), the corresponding model yielded a satisfactory to acceptable global model fit (CFI = 0.924, RMSEA = 0.073 [CI_{90} = 0.070–0.076], SRMR = 0.044, AIC = 134398, BIC = 134656). In particular, the descriptive values of the CFI and RMSEA improved substantially. Most importantly, the direct comparison between both variants clearly favored the model with the two parallel loadings (ΔSB-χ^2 = 736.6, Δdf = 2, $p <$ 0.001, ΔAIC = −1078, ΔBIC = −1065). Against this background, we continued the further validation and psychometric examinations with the parallel loading model only.

Table 2 Results of the exploratory item analyses

No.	Aspect	Item in English language (translated)	Descriptive statistics				
			Mean value (scale 1–5)	Standard deviation	Item diffi-culty	Skew-ness	Kurtosis
1	Manageability of endurance demands	I can maintain a slightly exhausting physical activity, which makes me breathe a little faster (e.g., walking, slow jogging or cycling), for 30 min without a break[a]	4.20	1.18	0.80	−1.46	1.10
2	Manageability of strength demands	I can lift an object that is approx. 10 kg several floors upwards (e.g., full shopping bag, filled suitcase, small beverage crate)[a]	3.98	1.36	0.75	−1.18	0.04
3	Manageability of balance demands	I can stand on one leg and reach for an object without losing balance[b]	3.79	1.43	0.70	−0.87	−0.65
4	Movement and body awareness	My body awareness helps me to master physically demanding situations well[b]	3.96	1.18	0.74	−0.99	0.11
5	Control of physical load	I am able to adjust my training effort well to my physical condition[b]	3.88	1.28	0.72	−0.98	−0.10
6	Control of physical load	I know how to use physical training to improve my endurance in the best possible way[b]	3.88	1.28	0.72	−0.99	−0.06
7	Control of physical load	I know what to pay attention to in relation to my body in order to avoid excess load or insufficient load[b]	4.19	1.00	0.80	−1.31	1.32
8	Affect regulation	I am well able to work off pent-up stress and inner tension through exercise[b]	3.68	1.25	0.67	−0.70	−0.48
9	Task-specific self-efficacy	I feel capable to perform physical activities that are challenging for me[b]	3.70	1.29	0.68	−0.77	−0.46
10	Self-control	When I decide to do more exercise, I am very disciplined in implementing this plan[b]	3.40	1.22	0.60	−0.34	−0.77
11	Motivational competence for exercise and sport	I am very able to choose from a variety of exercise and sport activities the one that suits me best[b]	3.95	1.24	0.74	−1.09	0.19
12	Self-control	If I have planned to exercise, I generally follow through on this plan[b]	3.72	1.24	0.68	−0.78	−0.33

The total number of persons analyzed ranged between $n = 3897$ and $n = 3970$ (missing percentage between 0.4 and 2.2%)

[a]Answering options (items 1 + 2) subsequent inverted processing: 1 = "I can do this without any problems" [German: "Ich kann dies ohne Probleme"], 2 = "I have some slight problems" ["Ich habe leichte Probleme"], 3 = "I have moderate problems" ["Ich habe mäßige Probleme"], 4 = "I have major problems" ["Ich habe große Probleme"], 5 = "I cannot do this" ["Ich kann dies nicht"]

[b]Answering options (items 3–12): 1 = "does not apply" [German: "trifft nicht zu"] … 5 = "applies very much" ["trifft sehr zu"]

Reliability

The factor reliabilities (Table 3) of the three PAHCO sub-competencies within the CFA (parallel loading structure) were satisfactory ($0.78 \leq \omega \leq 0.84$). Importantly, the factor reliability would not decrease when removing any item. All items without a twofold assignment to a sub-component revealed item loadings $\lambda \geq 0.60$ (Fig. 2). Only the seventh item (an operationalization of control of physical load) had a slightly lower coefficient ($\lambda = 0.54$). The two items with parallel loadings shared their variance between the two respective latent factors, yet consistently exceeded loadings $\lambda \geq 0.30$ (Fig. 2).

Criterion validity

All three latent sub-competencies of PAHCO correlated significantly with the physical activity behavior ($0.201 \leq \beta \leq 0.274$, $p < 0.001$), low-to-moderate in size (Table 3). Similarly, all sub-competencies of PAHCO were related to the self-reported health status, with a consistently high effect size ($0.498 \leq \beta \leq 0.652$, $p < 0.001$). We registered variations in the magnitudes of these associations across both outcomes. In exploratory comparisons, self-regulation competence was more strongly associated with leisure-time physical activity than movement competence ($z = 3.51$, $p < 0.001$). Movement competence, in turn, was more strongly related to the self-reported health status than self-regulation competence ($z = 10.2$, $p < 0.001$).

Measurement invariance

The factor structure of the parallel loading model turned out to be completely invariant for *gender* (Table 4). We registered acceptable scalar invariance of the measurement model for *age*. While we found a disproportionate decrease for this step in the CFI coefficient, the changes of the
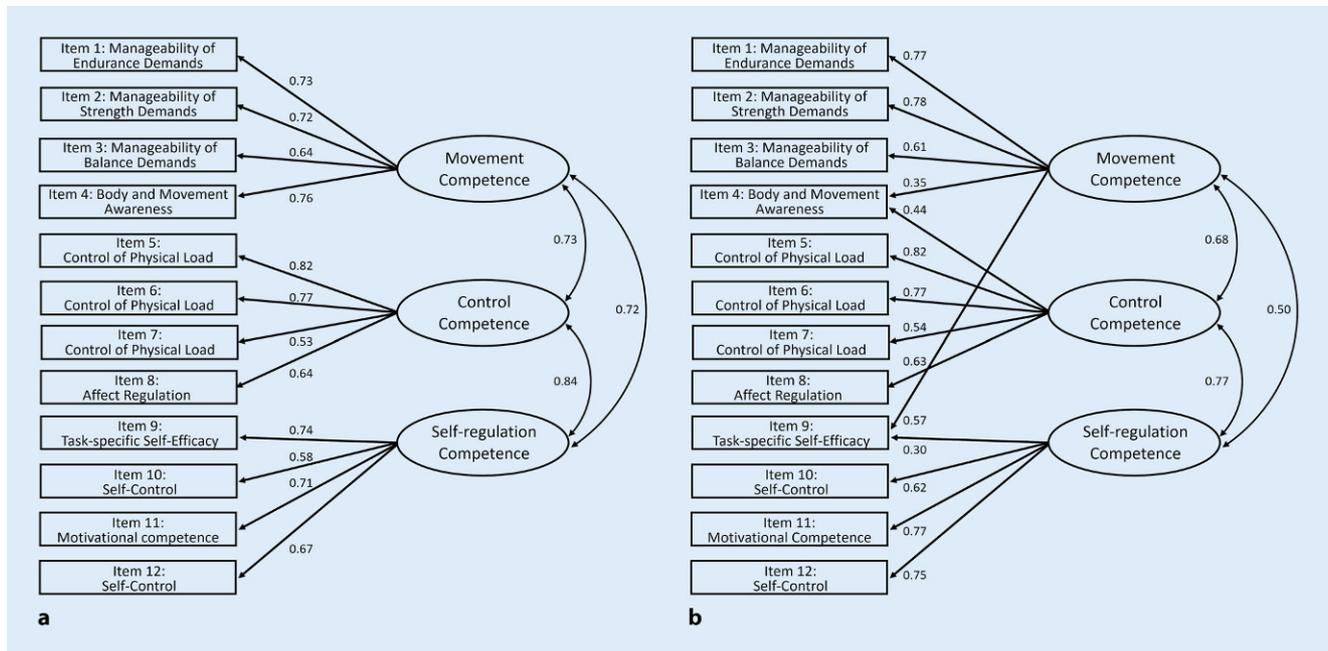
Fig. 2 ▲ Results of the simple loading (**a**) and the parallel loading structure (**b**) via confirmatory factor analysis. Note: λ represent the factor loadings; direct model comparisons favored the second model variant ($N = 3986$): $\Delta SB\text{-}\chi(2)^2 = 736.6$, $p < 0.001$, $\Delta AIC = -1078$, $\Delta BIC = -1065$

RMSEA and SRMR were still acceptable. Strict invariance could not be maintained for the age variable. The successive restrictions for the *education* variable could still be maintained until the restriction of intercepts (scalar invariance). While the CFI fell substantially when restricting the residuals, the changes in the two other indicators (RMSEA, SRMR) still suggested strict invariance of the measurement model for education.

Overall score of PAHCO_12 and subscores

In the last step, we converged all 12 items to a single overarching PAHCO factor. All items entered the overall score equally. We ascertained a McDonald's $\omega = 0.90$ for this scale, with no item causing a reduction in overall reliability. Similar as to the individual sub-competencies, the manifest PAHCO_12 score correlated significantly with leisure-time physical activity ($r = 0.233$, $p < 0.001$) and the self-reported health status ($r = 0.541$, $p < 0.001$). ◘ Table 5 illustrates and summarizes the formula for the sub-competencies and the overall PAHCO score as supported by the present validity findings.

Discussion

To the best of our understanding, there is currently no study in Germany that has representatively assessed behavior-oriented (i.e., physical, cognitive, motivational) determinants for physically active lifestyles in adulthood. The present analysis marked the technical prerequisite for a further characterization of these determinants on the population level by adjusting a long version of the PAHCO questionnaire and deriving a 12-item short version for a telephone-based assessment: the PAHCO_12. Given the number of items reserved for the implementation into the survey, we had to adequately manage the trade-off between covering the breadth of the concept, on the one hand, and the fulfillment of psychometric qualities, on the other.

According to initial descriptive analyses, all 12 items demonstrated satisfactory characteristics (in terms of item skewness and kurtosis) while also exhibiting favorable item difficulties on the scale. For purposes of differentiation, it may have been desirable to register stronger variations in the difficulty across the items, especially within the operationalized sub-competencies. However, as this short version

of PAHCO only intended to maintain the multifaceted nature of the model components (instead of precisely combining different item difficulties), this claim lay beyond the scope of this instrument. Against this background, the descriptive results entitle us to qualify the 12-item instrument as a screening instrument to economically gain insights into PAHCO. Nevertheless, we identified a factor structure that harmonized with the basic postulates of the PAHCO model (Carl et al., 2020a; Sudeck & Pfeifer, 2016). Similar as to the findings of the validation study for the long version of PAHCO (Carl et al., 2020b), the CFAs favored a model variant in which two parallel loading on two sub-components were considered. First, the measurement model considered task-specific self-efficacy as a requirement for the uptake of basic motor activities (i.e., consideration of movement competence in addition to self-regulation competence). In this regard, the results of the nested comparisons stood empirically in line with a meta-analysis indicating that exactly this task-specific interpretation of self-efficacy may play a stronger role for the short-term uptake of actions, whereas behavioral/barrier-specific self-efficacy tended to unfold their poten-

Table 3 Factor reliability (ω) and criterion validity of the three sub-competences of PAHCO

Sub-competences	Number of items	Reliability aspects		Criterion validity	
		McDonald's ω (factor reliability)	Part-whole correlations (item level)	Leisure-time physical activity (as outcome)	Self-reported health (as outcome)
Movement competence	5	0.84	0.57–0.67	$\beta = 0.201, p < 0.001$	$\beta = 0.652, p < 0.001$
Control competence	5	0.82	0.53–0.71	$\beta = 0.244, p < 0.001$	$\beta = 0.551, p < 0.001$
Self-regulation Competence	4	0.78	0.51–0.65	$\beta = 0.274, p < 0.001$	$\beta = 0.498, p < 0.001$

Global model fits of the structural equation model (SEM) when adding the two outcomes: movement competence (CFI = 0.921, RMSEA = 0.067, SRMR = 0.048), control competence (CFI = 0.898, RMSEA = 0.076, SRMR = 0.051), self-regulation competence (CFI = 0.883, RMSEA = 0.082, SRMR = 0.060)

Table 4 Analysis of measurement invariance

Variable of interest	Type of invariance	Global model fits					
		CFI	ΔCFI	RMSEA	ΔRMSEA	SRMR	ΔSRMR
Gender (male: $n = 2111$, female: $n = 1858$)	Configural	0.927	–	0.091	–	0.045	–
	Metric	0.925	−0.002	0.087	−0.004	0.049	0.004
	Scalar	0.913	−0.012	0.090	0.003	0.054	0.005
	Strict	0.907	−0.006	0.089	−0.001	0.057	0.003
Age (18–35 years: $n = 458$, 36–50 years: $n = 704$, 51–65 years: $n = 1257$ 66–80 years: $n = 1098$, >80 years: $n = 469$)	Configural	0.918	–	0.073	–	0.048	–
	Metric	0.913	−0.005	0.070	−0.003	0.057	0.009
	Scalar	0.890	−0.023	0.074	0.004	0.063	0.006
	Strict	0.844	−0.046	0.082	0.008	0.082	0.019
Education (low: $n = 644$, moderate: $n = 1793$, high: $n = 1542$)	Configural	0.920	–	0.074	–	0.046	–
	Metric	0.918	−0.002	0.070	−0.004	0.050	0.004
	Scalar	0.912	−0.006	0.068	−0.002	0.051	0.001
	Strict	0.885	−0.027	0.074	0.006	0.058	0.007

Measurement invariance was only tested for the parallel loading model. The fit indices of the basic CFA model were CFI = 0.924, RMSEA = 0.073, and SRMR = 0.044

Table 5 Formula for the calculation of the scales as supported by the present validations

Score	Formula	Range of the scale	
		Lower limit	Upper limit
Movement competence	$Item\_1^{INV} + Item\_2^{INV} + Item\_3 + 0.5 * Item\_4 + 0.5 * Item\_9$	0	16
Control competence	$0.5 * Item\_4 + Item\_5 + Item\_6 + Item\_7 + Item\_8$	0	18
Self-regulation competence	$0.5 * Item\_9 + Item\_10 + Item\_11 + Item\_12$	0	14
PAHCO_12 (overall PAHCO score)	$Item\_1^{INV} + Item\_2^{INV} + Item\_3 + Item\_4 + Item\_5 + Item\_6 + Item\_7 + Item\_8 + Item\_9 + Item\_10 + Item\_11 + Item\_12$	0	48

[INV]The items 1 and 2 require inverting. Before scale formation, all items must be transformed from 1–5 to 0–4 (implying a subtraction of 1 for each item)

tial for long-term physical activity behavior (Higgins, Middleton, Winner, & Janelle, 2014). Second, the body and movement awareness item also loaded on control competence (in addition to movement competence). In summary, this path accounts for scholarly insights that individuals can draw on sensory inputs and interoceptive mechanisms (e.g., estimating the heart rate during movements) to instantly regulate the physical load (e.g., pacing behavior: (Smits, Pepping, & Hettinga, 2014; Thiel, Pfeifer, & Sudeck, 2018)). As a consequence of these two parallel loadings, the item reliabilities were slightly lower than when specifying single loadings, but this could be explained by the reflective measurement model (Hanafiah, 2020) characterizing the items as indicators of the latent constructs (i.e., the sub-competencies; and not the constructs as the result of the composition of different items). When interpreting the scales at the sub-competence level, the reliability analyses uncovered that all items made a significant contribution to their assigned scales. This finding may also be the result of the thematic breadth of the sub-competencies, as the PAHCO items represented idiosyncratic demands relevant for physically active lifestyles.

The present study also accumulated promising hints regarding the criterion validity of the instrument by displaying low-to-moderate relationships with self-reported physical activity during leisure time (as a behavioral variable) and high associations with the self-reported health status (as a trait-like status variable). Interestingly, two studies with multiple sclerosis and vocational education students employing the long versions of PAHCO found similar effect sizes for associations between the sub-competen-

cies of PAHCO and indicators of physical activity and health (Carl, Grüne, Popp, & Pfeifer, 2020; Carl, Hartung, Tallner, & Pfeifer, 2021). Accordingly, the accumulation of empirical data corroborates PAHCO as being localized between research on physical literacy and health (literacy) (Haible et al., 2020; Holler et al., 2023). While health literacy focuses on the ability of individuals dealing with information and applying it to inform healthy decisions, the concept of PAHCO allows to understand different sub-competencies specifically required to engage in a health-oriented physically active lifestyle. Finally, we also investigated whether the shortened questionnaire was invariant across age, gender, and education levels—the sociodemographic variables with the highest relevance for the public health surveillance in Germany (Robert Koch-Institut, 2015). In this regard, this study provided the psychometric basis for a more detailed analysis of PAHCO through a public health lens. Such a public health lens could involve empirical relationships between the 12-item PAHCO version and, for example, the three sociodemographic variables as mentioned above to identify population groups with different needs for physical activity promotion.

The present study has four major limitations. First, the adjustment relied on experts with a theoretical–thematic and methodological–organizational focus. Although the process started with a set of proven items, testing with the target group (e.g., via cognitive interviews) may have added value in terms of the acceptance and comprehensibility of the instrument. Second, we did not empirically test the potential loss in content validity due to the reduction in the number of items. As introduced, it was due to limited time frames (eight minutes within this GEDA wave) not possible to utilize a long(er) version of PAHCO, which induced us to control this validity step by a circular employment of two independent expertise groups (see, e.g., the theoretical elaborations for item selection in ◻ **Table 1**). Third, we embedded the telephone interviews into a clear temporal schedule to ensure organization and feasibility. We

cannot exclude that interviewers might have rigorously attached to these schedules, which might have, in single cases, unintentionally pressured individuals with a slower progressing time. Fourth, only one of the four control competence items addressed the alignment of physical activities with psychological health (item #8: "I am well able to work off pent-up stress and inner tension through exercise"). In this regard, the construction process has, as an outcome of the feedback cycles ensuring comprehensibility, indirectly prioritized the alignment with physical health (three items) within the operationalization of this sub-competence.

Conclusion

When designing systematic interventions with a focus on PAHCO or conducting elaborate associative analyses, we would refer to more comprehensive long versions of PAHCO questionnaire including multi-item sets for the sub-competencies of interest. However, the present study provided initial evidence for the reliability and validity of the 12-item, short version of the PAHCO questionnaire, the PAHCO_12. The validated tool delivers an overall score for PAHCO as well as specific information about individual's movement competence, control competence, and self-regulation competence. Given the modality applied in this survey, we can recommend interested stakeholders of this instrument to perform telephone interviews for the assessment of PAHCO among adults on the population level. When considering the current questionnaire for research projects, we would suggest this instrument as a screening tool, for communicating descriptive trends, or as a secondary outcome of a trial.

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Declarations

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