SportRXiv

Part of the Society for Transparency, Openness and Replication in Kinesiology (STORK)

Preprint
not peer reviewed

Development and Validation of the Physical Effort Scale (PES)

*For correspondence:

boris.cheval@ens-rennes.fr
Twitter (X): @chevalboris

maltagli@usc.edu
Twitter (X): @maltagliati_s

matthieu.boisgontier@uottawa.ca
Bluesky: @matthieuboisgontier.com

Boris Cheval[1,2,†,*], Silvio Maltagliati[3,4,†,*], Delphine S. Courvoisier[5,6], Samuele Marcora[7,8], & Matthieu P. Boigontier[9]

[1]Department of Sport Sciences and Physical Education, École normale supérieure de Rennes – Bruz, France
[2]Laboratory VIPS2, University of Rennes – Rennes, France
[3]Univ. Grenoble Alpes, SENS, F-38000 Grenoble, France
[4]Human and Evolutionary Biology Section, Department of Biological Sciences, University of Southern California, CA, USA
[5]Department of Medicine, University of Geneva, Switzerland
[6]Division of Rheumatology, Beau Séjour Hospital, Geneva University Hospital, Switzerland
[7]Endurance Research Group, School of Sport and Exercise Sciences, University of Kent, Canterbury, UK
[8]Department of Biomedical and Neuromotor Sciences (DIBINEM), University of Bologna, Italy
[9]School of Rehabilitation Sciences, Faculty of Health Sciences, University of Ottawa, Canada
[†]BC and SM contributed equally to this work.

Acknowledgement:
We would like to thank Bianca Saint-Denis and Simon Baudry for their help in the data acquisition.

Please cite as: Cheval, B., Maltagliati, S., Courvoisier, D.S., Marcora, S. & Boisgontier, M.P. (2022). Development and Validation of the Physical Effort Scale (PES). *SportRxiv*.

All authors have read and approved this version of the manuscript. This article was last modified on October 16, 2023.

ABSTRACT

Objectives: Previous literature has primarily viewed physical effort as an aversive experience. However, recent research suggests that effort can also be valued positively. These differences in approach and avoidance tendencies toward physical effort may play a key role in the self-regulation of physical activity behaviors. The aim was to develop a scale that measures these tendencies and can contribute to a better understanding of physical effort and how it affects behavior.

Methods: The Physical Effort Scale (PES) was developed through expert evaluation and cognitive interviews. In sample 1 (n = 680), content validity and dimensional structure was examined through principal component analysis and confirmatory factor analysis. Item reduction was conducted using item response theory. Construct validity was then explored using regression. Sample 2 (n = 297) was used to validate dimensional structure, internal consistency, and construct validity, and to assess test-retest reliability.

Results: Out of 44 items evaluated for content validity by nine external experts, 18 were selected and refined based on cognitive interviews. Exploratory factor analysis and item response analysis of sample 1 allowed to reduce the scale to 8 items measuring the tendency to approach (n = 4) and avoid physical effort (n = 4). Confirmatory factor analyses validated the two dimensions structure in both samples. The two subscales showed high internal consistency ($\alpha > 0.897$) and acceptable test-retest reliability (intraclass correlation > 0.66). Patterns of associations with other constructs showed expected relations.

Conclusions: The PES is a valid and reliable measure of individual differences in the valuation of physical effort. This scale can assess the propensity to engage in physically demanding tasks in non-clinical populations. The PES and its manual are available in the supplemental material.

Keywords: Exercise, Investigative Techniques, Motivation, Personality, Physical Exertion, Sports, Validation Study

INTRODUCTION

The perception of physical effort can be defined as the conscious sensation of the effort expended in performing a physical activity (Kent, 2006; Marcora, 2009). This perception is influenced not only by the task demands, capacity to meet these demands, and actual physical effort (Steele, 2020), but also by previous experience of similar effort, motivation, awareness, and affects (Abbiss et al., 2015; Cheval & Boisgontier, 2021). Effort minimization is the process that aims to achieve the most cost-effective behavior based on this perception (Cheval & Boisgontier, 2021; Cheval & Boisgontier, 2023).

Physical effort has been studied extensively in many fields, including exercise science, psychology, biomechanics, ethology, and neuroscience. Most of these studies suggest that, ceteris paribus, humans favor lower rather than higher effort (Bernacer et al., 2019; Klein-Flügge et al., 2016; Prévost et al., 2010; Skvortsova et al., 2014). Consistent with this suggestion, results robustly demonstrated that humans process physical effort as a cost in decision-making tasks, and minimize the physical effort required to obtain a given reward (Bernacer et al., 2019; Klein-Flügge et al., 2016; Prévost et al., 2010; Skvortsova et al., 2014). Moreover, when exposed to visual stimuli associated with different levels of effort, they experience greater difficulty avoiding or not responding to stimuli associated with lower effort (Cheval et al., 2020; Cheval et al., 2021; Cheval et al., 2018; Farajzadeh et al., 2023; Parma et al., 2023), supporting the idea that individuals are generally attracted toward effort minimization.

The perception of physical effort has been associated with specific brain regions, including the striatum, amygdala, supplementary motor area, and cingulate cortex (Bernacer et al., 2019; Prévost et al., 2010; Zénon et al., 2015). For example, dopamine function in the striatum and ventromedial prefrontal cortex has been shown to correlate with the willingness to exert greater effort for greater rewards (Treadway et al., 2012). Further, studies have identified differences in brain activation associated with the processing of physical effort that may underlie clinical conditions, such as behavioral apathy (Bonnelle et al., 2016; Pessiglione et al., 2018). Another study suggests that higher connectivity between the amygdala and the anterior cingulate cortex are associated with a greater ability to overcome the cost of physical effort (Bernacer et al., 2019). Taken together, this literature suggests that effort is an aversive experience, which explains the tendency to avoid unnecessary physical effort – i.e., effort that is considered avoidable or not necessary to achieve a goal. An effort can be evaluated as unnecessary if it does not serve the pursuit of a goal, is excessive, or could be replaced by a more efficient alternative.

While physical effort has primarily been viewed as an aversive experience, some studies show that effort can also be positively valued in humans and other species (Eisenberger, 1992; Friedrich & Zentall, 2004; Gunderson et al., 2013; Inzlicht et al., 2018; Leonard et al., 2017; Lin et al., 2021; Lydall et al., 2010; Norton et al., 2012). For example, recent evidence suggests that humans can learn to value cognitive effort positively (Clay et al., 2022; Lin et al., 2021). Moreover, large individual differences have been observed in the overall tendency to avoid unnecessary physical exertion (Strasser et al., 2020; Treadway et al., 2012). Notably, while these individual differences have mostly been treated as random error variance in laboratory tasks, they may in fact be critical in explaining the regulation of effort-based behaviors, of which physical activity is the archetype (Maltagliati et al., 2022). For example, people with a strong tendency to approach physical effort may find it easier to follow through on their intentions to be physically active than people with a strong tendency to avoid physical effort. While previous studies showed large individual differences in the processing of physical effort, no scale has been developed to capture such differences.

Despite its importance, the study of the influence of individual differences in the valuation of physical effort on the regulation of physical activity is currently limited by the lack of an available instrument to measure these differences. Thus, the development of a short and easy-to-use scale that captures individual differences in the tendencies to approach and avoid physical effort is warranted. The objective of the present study is to report on the development and validation of such a scale.

METHODS

Study Design

The study included two phases: Scale development and scale validation. The scale development phase included the following steps: Domain identification, comparison with existing scales, content validity of the developed items, and cognitive interview to refine the items. The scale validation phase included the following steps: Structural validity, internal validity, concurrent validity, convergent validity, discriminant validity, and test-retest reliability. These steps are detailed below. The study was approved by the Ethics Committee of the Canton of Geneva, Switzerland (CCER2019-00065) and the Research Ethics Board of the University of Ottawa, Canada (H-07-22-8284).

Item and Scale Development

Consistent with previous recommendations (Boateng et al., 2018), we first defined the domain of interest being examined. Then, we developed an initial item pool under the supervision of a psychometrics expert (DSC). Regarding domain identification, we conducted a literature review to delineate the construct of interest and confirmed that there were no existing scales that adequately captured this construct. Specifically, based on the existing literature and two online meetings between the authors, we formally defined the concept of "perception of physical effort" that we aimed to capture: The conscious sensation of the effort expended in performing a physical activity. We then concluded that we wanted to develop a scale that would capture individual differences in the tendencies to approach and avoid physical effort, i.e., a propensity to perceive physical effort as aversive and thus tend to avoid situations evaluated as physically effortful, or a propensity to perceive physical effort as positive and thus tend to approach these situations.

We identified several existing scales related to the measurement of approach versus avoidance tendencies and of the processing of physical or cognitive effort. Specifically, we identified scales assessing approach and avoidance tendencies in a general context (e.g., approach and avoidance temperament questionnaire (Elliot & Thrash, 2010), the behavioral inhibition system (BIS) / behavioral activation system (BAS) questionnaire (Carver & White, 1994), and the reinforcement sensitivity theory of personality questionnaire (Corr & Cooper, 2016)) and in specific contexts (e.g., brief approach and avoidance of alcohol questionnaire (Levine et al., 2019), food approach and avoidance questionnaire (Rancourt et al., 2019). Regarding the scales measuring the processing of effort, we have identified the subjective need for cognition scale (Cacioppo & Petty, 1982; Cacioppo et al., 1996), the mental effort tolerance scale (Dornic et al., 1991), and the preference for and tolerance of the intensity of exercise questionnaire (Ekkekakis et al., 2005), which are scales capturing individual differences in the processing of physical or mental effort. Collectively, these scales confirmed the relevance of capturing on approach and avoidance tendencies as fundamental features of human behavioral regulation (Carver, 2006; Davidson, 1998) and suggested that individual differences in effort processing could explain the regulation of physically effortful behaviors (Cheval & Boisgontier, 2021; Inzlicht et al., 2018).

Based on the domain identification procedure, we generated 57 items to measure the tendency to approach or avoid physical effort. A panel of four experts in psychology, physiology, or neuroscience of exercise and sport sciences who authored this article reviewed the items and retained 44 of them. To assess content validity, defined as "the adequacy with which a measure assess the domain of interest" (Hinkin, 1995), each item was evaluated by nine other experts who rated its relevance, clarity, and essentiality. Specifically, to assess item relevance, the experts used the following scale: 1 = not relevant; 2 = somewhat relevant; 3 = very relevant. To assess wording clarity, they answered on the following scale: 1 = not clear; 2 = item needs some revision; 3 = very clear. To assess essentiality (i.e., how necessary the question is), the experts used the following scale: 1 = not essential; 2 = useful but not essential; 3 = essential. Finally, for each item, the experts could add any recommendations for improvement. After discussing the recommendations for improvement, we dropped 26 items that were not sufficiently clear, relevant, or essential, resulting in an initial 18-item scale questionnaire (9 items for the approach dimension and 9 items for the avoidance dimension).

After this phase, cognitive interviews were conducted with 10 participants from the target population (i.e., 18 years and older and fluent in English). During these cognitive interviews, respondents first completed the questionnaire (~5 min). During the completion of the scale, the experimenter was quiet and discreetly checked if some items took longer to answer than others, which was not the case. The experimenter then asked the respondent to rate whether each item was clear and easy to answer, and if they had any recommendations for improvement. This procedure took approximately 10 minutes in total. Note that two experimenters conducted these cognitive interviews independently (five respondents for each). Each item was then carefully reviewed by a third experimenter and, if necessary, modified according to the respondents' suggestions. Since the suggestions for improvement were minor and easily included in the modified version of the items, the 18-item format of the questionnaire developed during the content validity phase was retained.

Questionnaires and Variables for Construct Validity

Participants were recruited from research participation pool of a Canadian university in exchange for partial course credits. Participants were screened on the platform to ensure that they all reported sufficient English language proficiency. All participants followed the procedure online and were asked to complete the study on a computer in a quiet environment. To assess test-retest reliability, respondents from the sample 2 were asked if they would be willing to complete a short (approximately 5 min) questionnaire again one week later.

According to recommendations (Terwee et al., 2007), a study sample of at least 180 participants was required to explore the structure and reliability of a scale of 18 items (number of items × 10), which was the number of items retained after the item development and scale development phases (please see below). Respondents were excluded if they were under 18 years of age or not fluent in English. Principal component analysis, exploratory factor analyses, item response theory (sample 1), and confirmatory analyses (samples 1 and 2) were used to validate the structure of the scale. Internal consistency and construct validity were then estimated (samples 1 and 2).

Participants completed the 18 items resulting from the item and scale development process, as well as several questionnaires to measure construct validity. Specifically:

Concurrent validity: Usual level of physical activity as measured by the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003).

Convergent validity: Autonomous motivation for physical activity (Brunet et al., 2015; Maltagliati et al., 2021; Sheldon & Elliot, 1998), automaticity toward physical activity (Gardner et al., 2012), affective attitudes toward physical activity (Ekkekakis et al., 2021), and self-efficacy toward physical activity (Ajzen, 1991). Hierarchical regression analyses were then conducted to examine the ability of the approach and avoidance tendencies to explain the usual level of moderate-to-vigorous physical activity (MVPA) and time spent sitting, accounting for the effect of age, gender, intentions, instrumental attitudes, and self-efficacy.

Discriminant validity: Controlled motivation for physical activity (Brunet et al., 2015; Maltagliati et al., 2021; Sheldon & Elliot, 1998), instrumental attitudes toward physical activity (Ajzen, 1991), approach-avoidance temperament (Elliot & Thrash, 2010), and the need for cognition (Cacioppo & Petty, 1982; Cacioppo et al., 1996). The approach and avoidance temperaments questionnaire was designed to ensure that the PES was distinct from general approach and avoidance tendencies. The need for cognition was used to verify that the PES was distinct from a measure of cognitive effort, thereby ensuring that the PES target a construct that differs from a general effort processing.

Based on previous literature, our construct validity hypotheses were as follows. First, we expected that a higher usual level of physical activity would be associated with a higher tendency to approach physical effort and a lower tendency to avoid physical effort. Second, we hypothesized that a higher tendency to approach physical effort would be associated with autonomous motivation, positive affective attitudes, higher self-efficacy, higher intentions to engage in physical activity, and higher exercise automaticity, whereas a higher tendency to avoid physical effort would show the opposite pattern. We expected to observe moderate correlations of the PES (i.e., both approach and avoidance dimensions) with controlled motivation, instrumental attitudes, general approach-avoidance temperament, and the tendency to engage in cognitive effort. Finally, using hierarchical regression analyses, we hypothesized that both dimensions of the PES (i.e., avoidance and approach) would explain additional variance in usual MVPA and time spent sitting after accounting for the variance explained by the other constructs (i.e., attitudes, behavioral intentions, self-efficacy).

Validity and Reliability

The content validity of the shortened scale was assessed by a panel of experts to verify that the items still covered the relevant dimensions. Global reliability of each subscale was assessed using Cronbach's alpha. Similarity of scores between the baseline survey and the one-week retest was assessed using the weighted kappa statistic for items and the intraclass coefficient of correlation for subscale scores. All analyses were conducted using R version 4.3.1 (R Core Team, 2022).

Administration of the PES

The PES can be administered in person or online. The questionnaire has been used with respondents 18 years of age and older. Participants are instructed to indicate their level of agreement with each of the 8 items on a Likert scale anchored with (1) I completely disagree, (2) I disagree, (3) I neither agree nor disagree, (4) I agree, (5) I completely agree. The 18-item version of the PES takes approximately 5 minutes to complete, while the 8-item version takes approximately 2 minutes. The PES and its manual are available in the supplemental material.

Data and code sharing

In accordance with good research practices (Boisgontier, 2022), the data and code are publicly available online: https://zenodo.org/uploads/8358572

RESULTS

Study 1

Study Sample

A total of 680 English-speaking undergraduate students from the University of Ottawa completed the questionnaire in exchange for course credit. The students came from the Faculty of Social Sciences (161, 23.7%), Faculty of Health Sciences (157, 23.1%), Telfer School of Management (149, 21.9%), Faculty of Science (131, 19.3%), Faculty of Arts (52, 7.7%), Faculty of Engineering (28, 4.1%), and Faculty of Medicine (n = 1). One student did not specify their faculty. 85% of the students were in the first year or second year of their program. Participants had a mean age of 19.1 ± 2.2 years, and 69.4% (472) were female. Based on the Saltin-Grimby physical activity level scale (Grimby et al., 2015), participants self-reported being inactive (n = 143, 21%) or engaging in light (n = 232, 34%), moderate (n = 192, 28%), or vigorous physical activity (n = 113, 17%). The mean approach and avoidance tendency toward physical effort was of 3.45 ± 0.92 and 2.46 ± 1.00, respectively (Table 1).

Table 1. *Descriptive statistics*

		Sample 1	**Sample 2**
Characteristics	**Categories**	**N (%)**	**N (%)**
Sex	Female	472 (69.5)	210 (70.7)
	Male	200 (29.5)	79 (26.6)
	Prefer not to disclose	4 (0.6)	3 (1.0)
	These options do not apply to me	4 (0.4)	5 (1.7)
Age		19.1 (2.2)	20.3 (3.5)
Faculty or School	Social Sciences	161 (23.7)	64 (21.5)
	Health Sciences	157 (23.1)	77 (25.9)
	School of Management	149 (21.9)	22 (7.4)
	Science	131 (19.3)	88 (29.6)
	Arts	52 (7.7)	21 (7.1)
	Engineering	28 (4.1)	20 (6.7)
	Medicine	1 (0.15)	3 (1.0)
	Education	-	1 (0.3)
	Not reported	1 (0.15)	1 (0.3)
Program year	1st	388 (57.1)	88 (29.6)
	2nd	190 (27.9)	75 (25.3)
	3rd	52 (7.6)	71 (23.9)
	4th	34 (5.0)	55 (18.5)
	5th	13 (1.9)	4 (1.3)
	Other	3 (0.4)	4 (1.3)
Usual physical activity level	Inactive	143 (21.0)	54 (18.1)
	Light physical activity	232 (34.1)	98 (33.0)
	Moderate physical activity	192 (28.3)	102 (34.3)
	Vigorous physical activity	113 (16.6)	40 (13.5)
Score, mean (SD)	Approach to physical effort	3.45 (0.92)	3.59 (0.88)
	Avoid to physical effort	2.46 (1.00)	2.48 (0.99)

Notes. PA = physical activity. The usual level of physical activity was assessed using the Saltin-Grimby physical activity level scale (Grimby et al., 2015). Scores from the approach and avoidance tendencies toward effort were based on the 8-item scale.

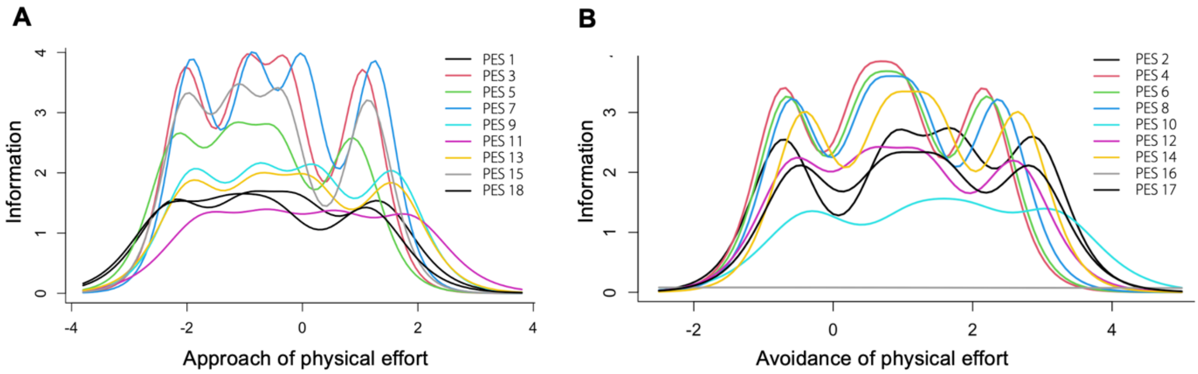
Structure of the Instrument

The results of the principal component analysis conducted on the 18 items suggested a 3-component solution based on eigenvalues greater than 1, while the scree plot favored a 1-factor solution. Since the theoretical model suggested 2 factors, we conducted three subsequent factor analyses with 1, 2, and 3 factor solutions. The results of the 3-factor analysis showed that one item (item 10) loaded on a factor, while the results of the 1-factor analysis clearly showed that the items theoretically related to the approach dimension loaded positively on this factor and that the items theoretically related to the avoid dimension loaded negatively on this factor. Moreover, the 2-factor analysis showed that the 9 items related to the approach dimension loaded on factor 1 (> 0.639) and that 8 items related to the approach dimension loaded on factor 2 (> 0.603). Only one item (item 16) had a low loading on factor 2 (0.318) (Table 2).

Item response theory analyses for each scale separately showed that items 1, 5, 9, 11, and 13 for the approach dimension, and items 2, 8, 10, 14, and 16 for the avoidance dimension could be dropped because their information functions were low, suggesting that they were not very informative, and/or because their item difficulties were redundant with other items (Figure 1). Four items were thus retained per dimension: items 3, 7, 15, and 18 for the approach dimension, and items 4, 6, 12, and 17 for the avoidance dimension (Table 2).

A principal component analysis of the selected 8 items showed that the first two components explained 68.7% of the variance. The 8-item PES scale retained good content validity covering both the orientation (i.e., approach vs. avoidance) and the affective aspects (i.e., negative vs. positive affect) of the processing of physical effort. Reliabilities for both dimensions were good, with Cronbach's alpha coefficients of 0.897 for the approach dimension and 0.913 for the avoidance dimension.

Figure 1. *Item information curves for the 18 items resulting from the item and scale development process, presented by subscale.*



Notes. Subscale numbers correspond to the item numbers in Table 2.

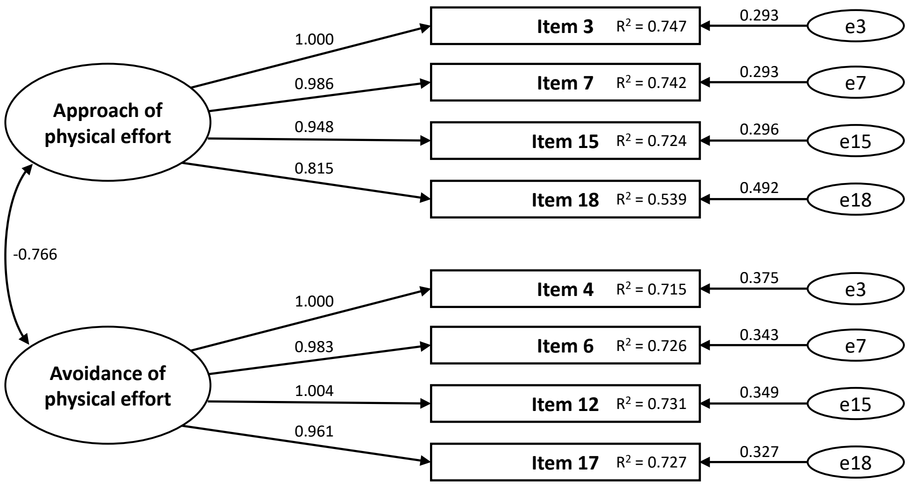
Table 2. *Factor loading of the 18 items resulting from the item and scale development process,*

Items	Factor 1	Factor 2
1. I tend to engage in tasks that require physical effort.	0.661	-0.148
2. I generally avoid situations that involve physical effort.	-0.172	0.724
3. I usually like activities that require physical effort.	0.801	
4. I tend to avoid situations in which I have to exert physical effort.		0.852
5. I usually find satisfaction in exerting physical effort.	0.752	
6. I tend to stay away from tasks that require physical effort.		0.841
7. The idea of exerting physical effort usually appeals to me.	0.851	
8. I tend to avoid tasks that require physical effort.		0.880
9. I usually like to engage in physical effort even if there are other possibilities.	0.832	
10. I generally do not find any satisfaction when I make a physical effort.	-0.137	0.603
11. I tend to search for opportunities to exert physical effort.	0.856	0.130
12. Exerting physical effort does not appeal to me.	-0.237	0.654
13. I tend to engage in situations in which I have to exert physical effort.	0.779	
14. When I have to engage in a physical effort, I usually seek to avoid it.		0.843
15. I generally enjoy activities that involve physical effort.	0.753	-0.103
16. I usually exert physical effort when there is no other alternative.		0.318
17. I usually dislike activities that involve physical effort.	-0.154	0.705
18. I am usually willing to engage in activities that involve physical effort.	0.639	

Notes. Promax rotation was used for the factor analysis. The number preceding each item indicates its position in the scale. Loadings below 0.1 in absolute value were not included in the table. Items selected for the final PES are in bold.

To further assess the structural validity of the 8-item PES, a confirmatory factor analysis was conducted using the `sem` function of the `lavaan` R package (Rosseel, 2012). Results showed that the hypothesized 2-factors structure fit the data adequately, yielding Chi^2 (19) = 56.0, p < 0.001, CFI = 0.990, TLI = 0.986, SRMR = 0.017, RMSEA = 0.055 (90% confidence interval [90CI] = 0.039 – 0.073; p <= 0.05 = 0.274). The factor loading, variance, and R^2 are presented in Figure 2. Loadings were very similar across items, supporting the possibility to averaging items to obtain scale scores. The approach tendency toward physical effort was significantly and negatively correlated with the avoidance tendency toward physical effort (r = -0.77; p < 0.001).

Figure 2. *Results of the confirmatory factor analysis of the 8-item physical effort scale (PES) for Sample 1 (n = 680)*



Notes. R^2 = percentage of variance explained; e = error variances

Preliminary Construct Validity

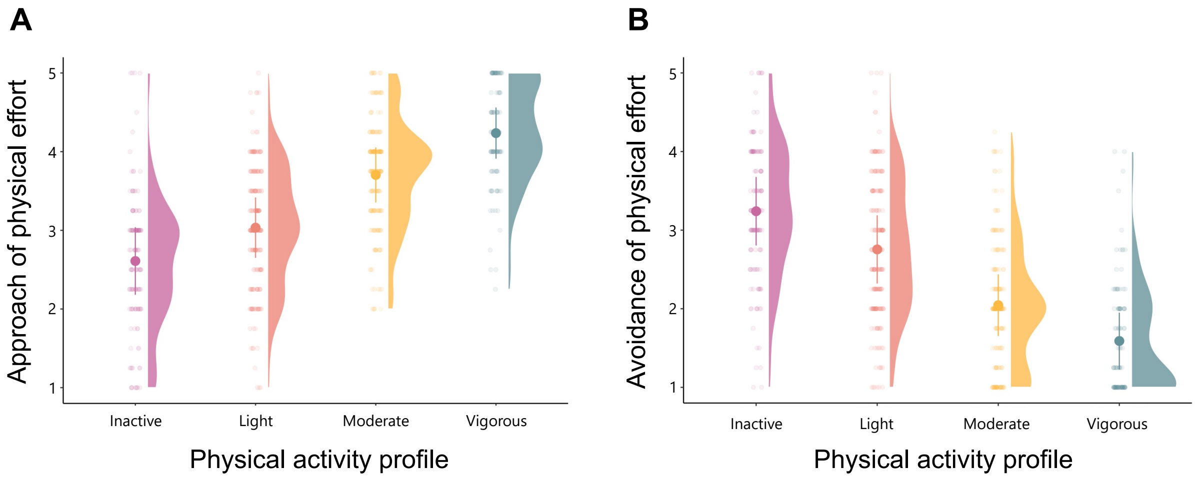
The results of the multiple linear regression analyses showed that participants' levels of physical activity – measured by the Saltin-Grimby scale – was associated with both approach and avoidance tendency toward physical effort (*p* for global effect < 0.001 for both approach and avoidance tendency) (Table 3). Specifically, approach tendency toward physical effort increased with increasing levels of physical activity, whereas the avoidance tendency toward physical effort decreased with increasing levels of physical activity (Figure 3). The percentage of variance explained was of 35.9% and 32.8% for approach and avoidance tendencies toward physical effort, respectively.

Table 3. *Results of the multiple linear regression testing the association of the physical activity levels with approach and avoidance tendencies toward physical effort.*

Outcomes	**Approach physical effort**		**Avoid physical effort**	
	b (95% CI)	*p*	b (95% CI)	*p*
Intercept	2.70 (2.57; 2.82)	< 0.001	3.24 (3.10; 3.38)	< 0.001
Usual level of physical activity (inactive ref.)				
Light physical activity	0.47 (0.31; 0.73)	< 0.001	-0.49 (-0.66; -0.30)	< 0.001
Moderate physical activity	1.15 (0.98; 1.31)	< 0.001	-1.20 (-1.38; -1.01)	< 0.001
Vigorous physical activity	1.59 (1.40; 1.78)	< 0.001	-1.65 (-1.86; -1.44)	< 0.001
Adjusted R^2	0.359		0.328	

Note. 95% CI = 95% confidence interval.

Figure 3. *Association between approach and avoidance tendencies toward physical effort and the level of physical activity.*



Note. Physical activity profile was assessed using Saltin-Grimby physical activity level scale.

Study 2

Study Sample

A total of 297 English-speaking undergraduate students from the University of Ottawa completed the questionnaire in exchange for course credit. The students came from the Faculty of Sciences (n = 88, 29.6%), Faculty of Health Sciences (n = 77, 25.9%), Faculty of Social Sciences (64, 21.5%), Telfer School of Management (n = 22, 7.4%), Faculty of Arts (n = 21, 7.1%), Faculty of Engineering (n = 20, 6.7%), Faculty of Medicine (n = 3, 1.0%), and Faculty of Education (n = 1). One student did not specify their Faculty. Students were in the first (n = 88, 29.6%), second (n = 75, 25.3%), third (n = 71, 23.9%), fourth (n = 55, 18.5%), or fifth (n = 4, 1.3%) year of their program. Four participants (1.3%) were in another situation. The mean age of the participants was 20.3 $\pm$ 3.5 years and 70.7% (n = 210) were female. Based on the Saltin-Grimby physical activity level scale, participants self-reported being inactive (n = 54, 18.1%) or engaging in light (n = 98, 33.0%), moderate (n = 102, 34.3%), or vigorous physical activity (n = 40, 13.5%). Three participants did not report their level of physical activity. The mean approach tendency toward effort was of 3.59 $\pm$ 0.88, while the mean avoidance tendency toward effort was of 2.48 $\pm$ 0.99 (Table 1).

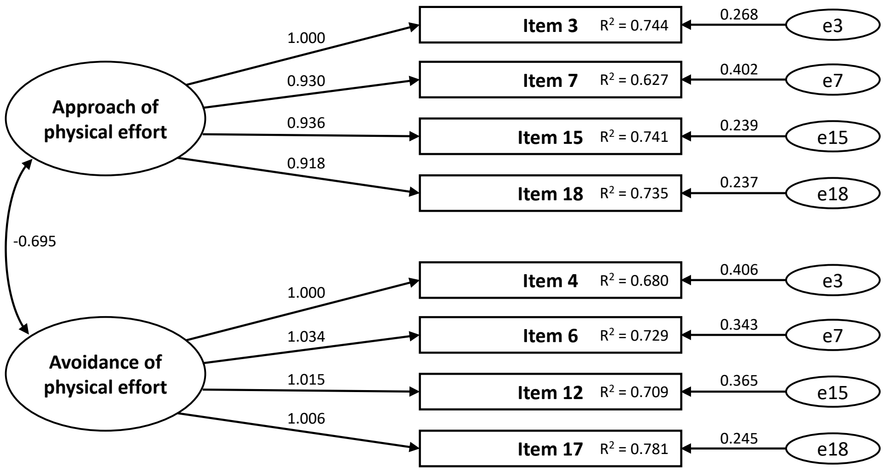
Table 4. Dimensions and items of the 8-item Physical Effort Scale (PES)

Dimension	Item
Approach of physical effort	3. I usually like activities that require physical effort.
	7. The idea of exerting physical effort usually appeals to me.
	15. I generally enjoy activities that involve physical effort.
	18. I am usually willing to engage in activities that involve physical effort.
Avoidance of physical effort	4. I tend to avoid situations in which I have to exert physical effort.
	6. I tend to stay away from tasks that require physical effort.
	12. Exerting physical effort does not appeal to me.
	17. I usually dislike activities that involve physical effort.

Structure Validation

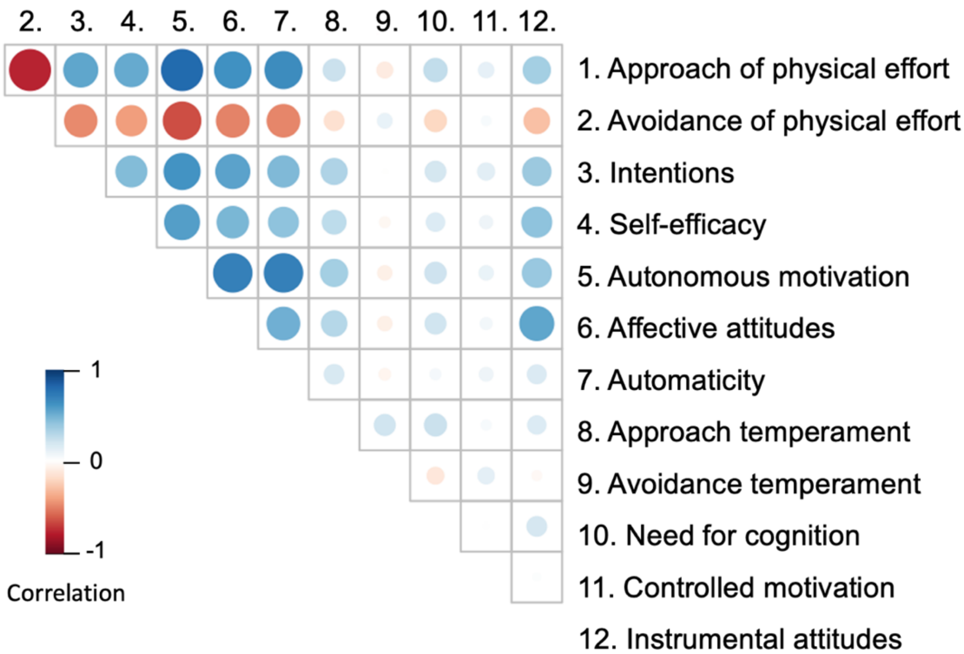
To assess the structural validity of the 8-item PES (Table 4), another confirmatory factor analysis was conducted using the `sem` function of the `lavaan` R package (Rosseel, 2012). The results showed that the hypothesized 2-factor structure fitted the data adequately, with Chi^2 (19) = 76.506, $p < 0.001$, CFI = 0.970, TLI = 0.955, SRMR = 0.027, although RMSEA = 0.101 (90CI = 0.078 – 0.125, $p >= 0.08$ = 0.934). Reliabilities of both dimensions were good, with Cronbach's alpha coefficients.

Figure 4. *Results of the confirmatory factor analysis of the 8-item physical effort scale (PES) for Sample 2 (n = 297)*



Notes. R^2 = percentage of variance explained; e = error variances

Figure 5. Illustration of the correlation of the approach and avoidance dimension of physical effort and the other assessed variables.



Construct Validity

Table 5 shows the associations between the approach and avoidance dimension of the PES with other variables for the assessment of concurrent (usual level of physical activity measured with the IPAQ), convergent (autonomous motivation, affective attitudes, self-efficacy, intentions), and discriminant validity (controlled motivation, instrumental attitudes, general approach-avoidance temperament, and the tendency to engage in cognitive effort). The associations were tested using univariate linear regressions and all the variables were scaled (i.e., means of 0 and standard deviation of 1) to obtain standardized coefficients. As expected, the approach and avoidance dimension of the PES were correlated with the usual level of physical activity and sitting time, supporting the concurrent validity of the scale. In addition, they had correlations ranging from .50 to .77 with autonomous motivation, affective attitudes, automaticity, and self-efficacy, demonstrating its convergent validity. Finally, results revealed the approach and avoidance dimensions of the PES exhibit correlations ranging from 0.10 to 0.33 for controlled motivation, instrumental attitudes, approach-avoidance temperament, and need for cognition, confirming its discriminant validity. Overall, the PES showed concurrent, convergent, and discriminant validity.

Table 5. *Concurrent, convergent, and discriminant validity of the approach and avoidance tendencies toward physical effort.*

	Approach of physical effort			Avoidance of physical effort		
	N	β	*p*	N	β	*p*
Concurrent validity						
Usual level of PA						
MVPA	296	0.29	<.001	296	-0.18	.002
Moderate PA	296	0.20	<.001	296	-0.13	.029
Vigorous PA	296	0.32	<.001	296	-0.20	<.001
Walking	296	-0.004	.945	296	-0.001	.984
Sitting	296	-0.26	<.001	296	0.25	<.001
Convergent validity						
Autonomous motivation	296	0.77	<.001	296	-0.64	<.001
Affective attitudes	295	0.61	<.001	295	-0.49	<.001
Self-efficacy	295	0.50	<.001	295	-0.41	<.001
Intentions	294	0.52	<.001	294	-0.47	<.001
Automaticity	294	0.61	<.001	294	0.48	<.001
Discriminant validity						
Controlled motivation	296	0.10	.091	296	0.03	.579
Instrumental attitudes	295	0.33	<.001	295	-0.29	<.001
Approach temperament	296	0.21	<.001	296	-0.16	.006
Avoidance temperament	296	-0.11	.059	296	0.10	.093
Need for cognition	296	0.24	<.001	296	-0.23	<.001

Notes. PA = Physical activity assessed with the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003); MVPA = usual level of moderate-to-vigorous physical activity. Univariate linear regressions were used to assess the associations. All the variables were scaled to obtain standardized coefficients.

Table 6 presents the results of the hierarchical regression analyses that explained usual MVPA. In Step 1, age, gender, instrumental attitudes, self-efficacy, and intentions were entered. In this model, gender ($\beta = 0.29$, $p = 0.023$) and intentions ($\beta = 0.29$, $p < 0.001$) were significantly associated with usual MVPA, explaining about 11% of the variance in usual MVPA. In Step 2, approach of physical effort only, avoidance of physical effort only, and both approach and avoidance of physical effort were entered. Results showed that both approach or avoidance tendency toward physical effort were, respectively, positively ($\beta = 0.16$, $p = 0.029$) and negatively ($\beta = -0.16$, $p = 0.022$) associated with usual MVPA, respectively. The model including the approach tendency explained 12.1% (i.e., an increase of 1.1%) of the variance in usual MVPA, and the model including the avoidance tendency explained 12.2% of the variance (i.e., an increase of 1.2%). In these models, intentions remained significantly associated with usual MVPA and the effect of gender became marginal (*ps* < 0.058). In the model that included both approach and avoidance tendencies, the associations between these tendencies and usual MVPA time became non-significant.

Table 6. *Results of the hierarchical regression analyses for explaining the usual level of MVPA.*

	Baseline		***Approach only***		***Avoidance only***		***Both tendencies***	
	β	***P***	**β**	***P***	**β**	***P***	**β**	***P***
Dependent variable: MVPA								
Step 1								
Age	0.06	0.262	0.06	0.32	0.05	0.362	0.05	0.357
Gender (ref. women)								
Men	0.29	0.023	0.25	0.058	0.25	0.051	0.24	0.064
Intention	0.29	< 0.001	0.23	< 0.001	0.23	< 0.001	0.22	0.002
Instrumental attitudes	-0.03	0.628	-0.04	0.556	-0.04	0.556	-0.04	0.544
Self-efficacy	0.07	0.306	0.01	0.840	0.01	0.03	0.01	0.544
Step 2								
Approach			0.16	0.029			0.08	0.380
Avoidance					-0.16	0.022	-0.09	0.298
R^2								
Adjusted R^2	0.108		0.121		0.122		0.121	

Notes. MVPA = usual level of moderate-to-vigorous physical activity. Multiple linear regressions were used to assess the associations. All the variables were scaled to obtain standardized coefficients.

We repeated the same analyses as in the previous section with usual sitting time replacing usual MVPA as the dependent variable (Table 7). In the model without approach and avoidance tendencies, intentions were significantly associated with usual sitting time (β = -0.23, *p* < 0.001). This model explained around 4.8% of the variance in usual sitting time. In the models including either approach or avoidance tendencies, the latter were negatively (β = -0.22, *p* = 0.003) and positively (β = 0.29, *p* = 0.006) associated with usual sitting time, respectively. Intentions became non-significant in these models. The model including the approach tendency explained 7.5% (i.e., an increase of 2.7%) of the variance in usual sitting time, and the model including the avoidance tendency accounted for 7.0% of the variance (i.e., an increase of 2.2%). In the model that included both approach and avoidance tendencies, the associations between these tendencies and usual sitting time became non-significant.

Therefore, based on these results, we decided to calculate a score that captures the relative tendency to approach rather than avoid physical effort as follows: Relative tendency to approach physical effort = Averaged score for tendency to approach physical effort – Averaged score for tendency to avoid physical effort. A higher score indicates a greater tendency to approach (rather than avoid) physical effort. We ran the same regression analyses as above using the relative score instead of the approach and avoidance scores separately. Results showed that both intentions (β = 0.19, *p* = 0.002) and relative tendency toward physical effort (β = 0.16, *p* = 0.014) were significantly associated with usual MVPA, explaining 12.4% of the variance in usual MVPA. We observed a similar pattern of results for time spent sitting, with both intentions (β = -0.14, *p* = 0.040) and relative tendency toward physical effort (β = -0.23, *p* = 0.002) significantly related to time spent sitting. The model explained 7.7% of the variance in usual time spent sitting.

Test-Retest Reliability

The test-retest agreement was satisfactory for all items of the PES (weighted kappa range: 0.41 to 0.61, mean = 0.49). For the 4-item subscales, test-retest agreement was 0.78 (95CI: 0.72 – 0.83) for the approach physical effort dimension, and 0.66 (95CI: 0.57 – 0.73) for the avoidance physical effort dimension. These results confirmed the satisfactory test-retest reliability of the PES.

Table 7. *Results of the hierarchical regression analyses for explaining usual level of time spent sitting.*

	Baseline		***Approach only***		***Avoidance only***		***Both tendencies***	
	β	***P***	**β**	***P***	**β**	***P***	**β**	***P***
Dependent variable: Usual sitting time								
Step 1								
Age	-0.03	0.613	-0.02	0.731	-0.01	0.801	-0.02	0.785
Gender (ref. women)								
Men	-0.12	0.369	-0.05	0.691	-0.07	0.608	-0.05	0.715
Intention	-0.23	<0.001	-0.16	0.026	-0.16	0.021	-0.15	0.040
Instrumental attitudes	0.05	0.444	0.06	0.361	0.06	0.370	0.06	0.353
Self-efficacy	-0.05	0.462	0.02	0.586	-0.001	0.991	0.02	0.724
Step 2								
Approach			-0.22	0.003			-0.16	0.127
Avoidance					0.19	0.006	0.09	0.355
R^2								
Adjusted R^2	0.048		0.075		0.070		0.074	

Notes. Multiple linear regressions were used to assess the associations. All the variables were scaled to obtain standardized coefficients.

DISCUSSION

In this study, we developed and validated the PES to measure individual differences in approach and avoidance tendencies toward physical effort. After item generation, content validity, and cognitive interviews for item improvement, factor analysis conducted on a first sample (n = 680) indicated that the two tendencies (i.e., approach and avoidance) could each be measured by 4 items. The resulting 8-item scale had very high internal consistency for both the approach (Cronbach alpha = 0.913) and avoidance dimension (Cronbach alpha = 0.897). Using a confirmatory factor analysis, the hypothesized 2-factor structure fitted the data well, confirming the structural validity of the 8-item scale. Finally, we showed that usual level of physical activity (assessed via the Saltin-Grimby questionnaire) was positively associated with the approach tendency toward physical effort, whereas it was negatively associated with the avoidance tendency, providing preliminary evidence for the construct validity of the scale. These findings were consistent with our conceptual reasoning that general tendencies to approach and to avoid physical effort could be empirically observed. They also provide initial evidence that these general tendencies toward physical effort may be involved in the regulation of physical activity.

In a second independent sample 2 (n = 297), the structural validity and the internal consistency of the 8-item scale was confirmed. Regarding construct validity, the approach dimension of the PES was positively associated with usual MVPA and negatively associated with usual sitting time (assessed using the IPAQ). The avoidance dimension of the PES showed the opposite pattern of associations. These findings confirmed that individual differences in the approach and avoidance tendencies toward physical effort may be involved in the regulation of physical activity and sedentary behavior. It should be noted, however, that the associations were of small to moderate magnitude on average ($r < 0.32$).

As hypothesized, approach and avoidance tendencies toward physical effort showed moderate to strong correlations with autonomous motivation, affective attitudes, automaticity, and self-efficacy ($rs > 0.41$ in absolute value) and small correlations with controlled motivation, instrumental attitudes, approach-avoidance temperaments, and need for cognition ($rs < 0.29$ in absolute value). These observations supported the convergent and discriminant validity of the PES. Importantly, regarding discriminant validity, these weak correlations suggested that the PES measures a construct that is distinct from the general approach-avoidance personality traits (Carver & White, 1994; Elliot & Thrash, 2010) and general effort processing (Cacioppo & Petty, 1982; Cacioppo et al., 1996). This finding holds significance as it was imperative to confirm that the scale could effectively captured a construct pertaining to the specific processing of physical effort, rather than more global individual differences, such as the inclination to approach or avoid daily life events, or the processing of other types of effort, such as cognitive effort.

We found that both approach and avoidance dimensions of the PES were significantly associated with usual MVPA, after controlling for the effects of age, gender, intentions, instrumental attitudes, and self-efficacy. However, as for the univariate models, the additional variance explained was small (i.e., around 1%). Of note, the associations between these tendencies and usual MVPA time became non-significant in the model that included both tendencies simultaneously. This result can be explained by the fact that, although conceptually and empirically distinct, the correlation between the two dimensions of the PES was high. We observed a similar pattern of results for sitting time: approach tendency toward physical effort was negatively associated with sitting time, whereas the avoidance tendency was positively associated with this time, over and above the effects of age, gender, intention, self-efficacy, and instrumental attitudes. In the model including both tendencies, neither the effect of the approach dimension nor the effect of the avoidance dimension remained significant. As for usual MVPA, this latter result could be explained by the high correlation between the two dimensions of the PES. Future research is needed to better understand whether both dimensions of the scale could predict different outcomes (e.g., physical activity maintenance for the approach dimension *and* physical activity initiation for the avoidance dimension). However, from a practical standpoint, researchers interested in exploring the role of these tendencies in the regulation of movement-based behaviors should examine each of these tendencies separately. Alternatively, it is also possible to create a relative score based on both tendencies by subtracting the avoidance tendency score from the approach tendency score. As demonstrated in additional analyses, this relative score was significantly related to both usual MVPA and usual time spent sitting, accounting for the effect of gender, intentions, self-efficacy, and attitudes.

The one-week test-retest reliability was good (intraclass coefficient of correlation for the 4-item approach physical effort dimension = 0.78 and for the 4-item avoidance physical effort dimension = 0.66). These findings are consistent with our conceptualization of the approach and avoidance tendencies toward physical effort as corresponding to a rather stable dispositional tendencies toward physical effort. Interestingly, the approach dimension seemed to be more stable than the avoidance dimension. Although this observation needs to be confirmed, it would suggest that the tendency to avoid physical effort may be more labile and sensitive to situational changes than the tendency to approach physical effort. Future studies should be conducted to examine whether the approach and avoidance tendencies respond differently to changes in the individual's situational states such as fatigue, stress, or a lack of available cognitive resources.

Lastly, descriptive results showed that, on average, participants reported a higher tendency to approach physical effort, as indicated by a score above the midpoint of the 1-5 scale

(3.45 and 3.59 for sample 1 and 2, respectively), than to avoid physical effort (2.46 and 2.48 for sample 1 and 2, respectively). At first glance, this finding may seem inconsistent with the current literature in neuroscience and psychology, which has robustly demonstrated that humans tend to avoid physical effort (Bernacer et al., 2019; Cheval & Boisgontier, 2021; Klein-Flügge et al., 2016; Prévost et al., 2010; Skvortsova et al., 2014). Yet, this gap can be explained by the well-known limitations associated with self-report measures, which can lead to inaccuracies in measuring the actual value of physical effort in real-life situations due to processes such as social desirability bias or inability to self-evaluate. What seems critical here is not to be able to determine whether, on average, participants were more inclined to approach or avoid physical effort, but to capture individual differences in these tendencies and to determine whether these differences can explain behavioral observations regarding decision-making processes related to effort-based behaviors. Consistent with this reasoning, we found that participants showed some variability in their responses, with a standard deviation slightly below 1 for both dimensions, and with scores that ranged across the possible values of PES (i.e., from 1 to 5) – although fewer participants scored 4 and 5 for the tendency to avoid physical effort. This large interindividual variability is consistent with existing literature that has also reported such individual differences in the tendency to avoid physical effort (Strasser et al., 2020; Treadway et al., 2012).

Limitations and Strengths

The main limitations of the study include the use of self-reported data to measure physical activity behaviors and the characteristics of the sample, which consisted mostly of young and well-educated adults. Future studies using device-measured of physical activity and recruiting a more diverse sample are needed. Moreover, testing the ability of the approach and avoidance dimensions to predict subsequent engagement in physical activity would allow assessing the predictive validity of the PES.

However, these limitations are outweighed by several strengths. We followed the steps recommended for scale development (Boateng et al., 2018): Domain identification, comparison with multiple existing scales, content validity of the items developed by nine independent experts, cognitive interview, internal consistency, construct validity (i.e., concurrent, convergent, and discriminant validity), and test-retest reliability. In addition, we relied on two relatively large independent samples, in which the structural validity of the scale, internal consistency, and concurrent validity were tested and validated.

In conclusion, the PES has sound psychometric properties for the study of individual differences in the valuation of physical effort. Because it is a short questionnaire (i.e., 4 items for the approach dimension and 4 items for the avoidance dimension), the PES can easily be included in research projects on physical activity, sedentary behavior, or physical effort in general. This would allow researchers to examine the extent to which the large individual differences in the processing of physical effort consistently found in previous studies could be explained by these tendencies (Strasser et al., 2020; Treadway et al., 2012). Future research is needed to adapt this scale to different populations, including children, older adults, or individuals with a clinical condition. The PES and its manual are available in the supplemental material.

REFERENCES

Abbiss, C. R., Peiffer, J. J., Meeusen, R., & Skorski, S. (2015). Role of ratings of perceived exertion during self-paced exercise: what are we actually measuring? *Sports Medicine*, *45*(9), 1235-1243. https://doi.org/10.1007/s40279-015-0344-5

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179-211. https://doi.org/10.1016/0749-5978(91)90020-T

Bernacer, J., Martinez-Valbuena, I., Martinez, M., Pujol, N., Luis, E. O., Ramirez-Castillo, D., & Pastor, M. A. (2019). An amygdala-cingulate network underpins changes in effort-based decision making after a fitness program. *NeuroImage*, *203*, 116181. https://doi.org/10.1016/j.neuroimage.2019.116181

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: A primer. *Frontiers in public health*, *6*, 149. https://doi.org/10.3389/fpubh.2018.00149

Boisgontier, M.P. (2022). Research integrity requires to be aware of good and questionable research practices. *European Rehabilitation Journal*, *2*(1), 1-3. https://doi.org/10.52057/erj.v2i1.24

Bonnelle, V., Manohar, S., Behrens, T., & Husain, M. (2016). Individual differences in premotor brain systems underlie behavioral apathy. *Cerebral cortex*, *26*(2), 807-819. https://doi.org/10.1093/cercor/bhv247

Brunet, J., Gunnell, K. E., Gaudreau, P., & Sabiston, C. M. (2015). An integrative analytical framework for understanding the effects of autonomous and controlled motivation. *Personality and Individual Differences*, *84*, 2-15. https://doi.org/10.1016/j.paid.2015.02.034

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*(1), 116. https://doi.org/10.1037/0022-3514.42.1.116

Cacioppo, J. T., Petty, R. E., Feinstein, J. A., & Jarvis, W. B. G. (1996). Dispositional differences in cognitive motivation: The life and times of individuals varying in need for cognition. *Psychological bulletin*, *119*(2), 197-253. https://doi.org/10.1037/0033-2909.119.2.197

Carver, C. S. (2006). Approach, avoidance, and the self-regulation of affect and action. *Motivation and Emotion*, *30*(2), 105-110. https://doi.org/10.1007/s11031-006-9044-7

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS scales. *Journal of Personality and Social Psychology*, *67*(2), 319-333. https://doi.org/10.1037/0022-3514.67.2.319

Cheval, B., Bacelar, M., Daou, M., Cabral, A., Parma, J., Forestier, C., Orsholits, D., Sander, D., Boisgontier, M., & Miller , M. W. (2020). Higher inhibitory control is required to escape the innate attraction to effort minimization. *Psychology of Sport and Exercise*, *51*, 101781. https://doi.org/10.1016/j.psychsport.2020.101781

Cheval, B., & Boisgontier, M. P. (2021). The theory of effort minimization in physical activity. *Exercise and Sport Sciences Reviews*, *49*(3), 168-178. https://doi.org/10.1249/JES.0000000000000252

Cheval, B., & Boisgontier, M. P. (2023). Promouvoir une activité physique régulière chez les patients: l'importance de la perception de l'effort. *STAPS*. https://doi.org/10.3917/sta.pr1.0091

Cheval, B., Cabral, D. A. R., Daou, M., Bacelar, M., Parma, J. O., Forestier, C., Orsholits, D., Maltagliati, S., Sander, D., & Boisgontier, M. P. (2021). Inhibitory control elicited by physical activity and inactivity stimuli: An EEG study. *Motivation Science*, *7*(4), 386-389. https://doi.org/10.1037/mot0000236

Cheval, B., Tipura, E., Burra, N., Frossard, J., Chanal, J., Orsholits, D., Radel, R., & Boisgontier, M. P. (2018). Avoiding sedentary behaviors requires more cortical resources than avoiding physical activity: An EEG study. *Neuropsychologia*, *119*, 68-80. https://doi.org/10.1016/j.neuropsychologia.2018.07.029

Clay, G., Mlynski, C., Korb, F. M., Goschke, T., & Job, V. (2022). Rewarding cognitive effort increases the intrinsic value of mental labor. *Proceedings of the National Academy of Sciences*, *119*(5), e2111785119. https://doi.org/10.1073/pnas.2111785119

Corr, P. J., & Cooper, A. J. (2016). The reinforcement sensitivity theory of personality questionnaire (RST-PQ): Development and validation. *Psychological Assessment*, *28*(11), 1427-1440. https://doi.org/10.1037/pas0000273

Craig, C. L., Marshall, A. L., Sjostrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J. F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise*, *35*(8), 1381-1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Davidson, R. J. (1998). Affective style and affective disorders: Perspectives from affective neuroscience. *Cognition & Emotion*, *12*(3), 307-330. https://doi.org/10.1080/026999398379628

Dornic, S., Ekehammar, B., & Laaksonen, T. (1991). Tolerance for mental effort: Self-ratings related to perception, performance and personality. *Personality and Individual Differences*, *12*(3), 313-319. https://doi.org/10.1016/0191-8869(91)90118-U

Eisenberger, R. (1992). Learned industriousness. *Psychological review*, *99*(2), 248-267. https://doi.org/10.1037/0033-295X.99.2.248

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2005). Some like it vigorous: Measuring individual differences in the preference for and tolerance of exercise intensity. *Journal of Sport and Exercise Psychology*, *27*(3), 350-374. https://doi.org/10.1123/jsep.27.3.350

Ekkekakis, P., Zenko, Z., & Vazou, S. (2021). Do you find exercise pleasant or unpleasant? The Affective Exercise Experiences (AFFEXX) questionnaire. *Psychology of Sport and Exercise*, *55*(10), 101930. https://doi.org/10.1016/j.psychsport.2021.101930

Elliot, A. J., & Thrash, T. M. (2010). Approach and avoidance temperament as basic dimensions of personality. *Journal of Personality*, *78*(3), 865-906. https://doi.org/10.1111/j.1467-6494.2010.00636.x

Farajzadeh, A., Goubran, M., Beehler, A., Cherkaoui, N., Morrison, P., de Chanaleilles, M., Maltagliati, S., Cheval, B., Millers M. W., Sheehy, L., Bilodeau, M., Orsholits, D., & Boisgontier, M.P. (2023). Automatic approach-avoidance tendency toward physical activity, sedentary, and neutral stimuli as a function of age, explicit affective attitude, and intention to be active. *Peer Community Journal*, *3,* e21. https://doi.org/10.24072/pcjournal.246

Friedrich, A. M., & Zentall, T. R. (2004). Pigeons shift their preference toward locations of food that take more effort to obtain. *Behavioural Processes*, *67*(3), 405-415. https://doi.org/10.1016/j.beproc.2004.07.001

Gardner, B., Abraham, C., Lally, P., & de Bruijn, G.-J. (2012). Towards parsimony in habit measurement: Testing the convergent and predictive validity of an automaticity subscale of the Self-Report Habit Index. *International Journal of Behavioral Nutrition and Physical Activity*, *9*, 102. https://doi.org/10.1186/1479-5868-9-102

Grimby, G., Börjesson, M., Jonsdottir, I., Schnohr, P., Thelle, D., & Saltin, B. (2015). The "Saltin–Grimby physical activity level scale" and its application to health research.

Scandinavian Journal of Medicine & Science in Sports, *25*, 119-125. https://doi.org/10.1111/sms.12611

Gunderson, E. A., Gripshover, S. J., Romero, C., Dweck, C. S., Goldin-Meadow, S., & Levine, S. C. (2013). Parent praise to 1-to 3-year-olds predicts children's motivational frameworks 5 years later. *Child Development*, *84*(5), 1526-1541. https://doi.org/10.1111/cdev.12064

Hinkin, T. R. (1995). A review of scale development practices in the study of organizations. *Journal of Management*, *21*(5), 967-988. https://doi.org/10.1016/0149-2063(95)90050-0

Inzlicht, M., Shenhav, A., & Olivola, C. Y. (2018). The effort paradox: Effort is both costly and valued. *Trends in Cognitive Sciences*, *22*(4), 337-349. https://doi.org/10.1016/j.tics.2018.01.007

Kent, M. (2006). *Oxford dictionary of sports science and medicine*. Oxford University Press. https://doi.org/10.1093/acref/9780198568506.001.0001

Klein-Flügge, M. C., Kennerley, S. W., Friston, K., & Bestmann, S. (2016). Neural signatures of value comparison in human cingulate cortex during decisions requiring an effort-reward trade-off. *Journal of Neuroscience*, *36*(39), 10002-10015. https://doi.org/10.1523/JNEUROSCI.0292-16.2016

Leonard, J. A., Lee, Y., & Schulz, L. E. (2017). Infants make more attempts to achieve a goal when they see adults persist. *Science*, *357*(6357), 1290-1294. https://doi.org/10.1126/science.aan2317.

Levine, J. A., Noyes, E. T., Gius, B. K., Ahlich, E., Rancourt, D., Houston, R. J., & Schlauch, R. C. (2019). Development and psychometric evaluation of a brief approach and avoidance of alcohol questionnaire. *Alcoholism: Clinical and Experimental Research*, *43*(2), 353-366. https://doi.org/10.1111/acer.13939

Lin, H., Westbrook, A., Fan, F., & Inzlicht, M. (2021). Instilling the value of effort (Registered report stage 2). https://doi.org/10.31234/osf.io/gnk4m

Lydall, E. S., Gilmour, G., & Dwyer, D. M. (2010). Rats place greater value on rewards produced by high effort: An animal analogue of the "effort justification" effect. *Journal of Experimental Social Psychology*, *46*(6), 1134-1137. https://doi.org/10.1016/j.jesp.2010.05.011

Maltagliati, S., Rebar, A., Fessler, L., Forestier, C., Sarrazin, P., Chalabaev, A., Sander, D., Sivaramakrishnan, H., Orsholits, D., & Boisgontier, M. P. (2021). Evolution of physical activity habits after a context change: The case of COVID-19 lockdown. *British Journal of Health Psychology*, *26*(4), 1135-1154. https://doi.org/10.1111/bjhp.12524

Maltagliati, S., Sarrazin, P., Fessler, L., LeBreton, M., & Cheval, B. (2022). Why people should run after positive affective experiences, not health benefits. *Journal of Sport and Health Science*. https://doi.org/10.1016/j.jshs.2022.10.005

Marcora, S. (2009). Perception of effort during exercise is independent of afferent feedback from skeletal muscles, heart, and lungs. *Journal of applied physiology*, *106*(6), 2060-2062. https://doi.org/10.1152/japplphysiol.90378.2008

Norton, M. I., Mochon, D., & Ariely, D. (2012). The IKEA effect: When labor leads to love. *Journal of Consumer Psychology*, *22*(3), 453-460. https://doi.org/10.1016/j.jcps.2011.08.002

Parma, J., Bacelar, M., Cabral, D., Recker, R., Renaud, O., Sander, D., Krigolson, O., Miller, M., Cheval, B., & Boisgontier, M. (2023). Relationship between reward-related brain activity and opportunities to sit. *Cortex*, *167*, 197-217. https://doi.org/10.1016/j.cortex.2023.06.011

Pessiglione, M., Vinckier, F., Bouret, S., Daunizeau, J., & Le Bouc, R. (2018). Why not try harder? Computational approach to motivation deficits in neuro-psychiatric diseases. *Brain*, *141*(3), 629-650. https://doi.org/10.1093/brain/awx278

Prévost, C., Pessiglione, M., Météreau, E., Cléry-Melin, M.-L., & Dreher, J.-C. (2010). Separate valuation subsystems for delay and effort decision costs. *Journal of Neuroscience*, *30*(42), 14080-14090. https://doi.org/10.1523/JNEUROSCI.2752-10.2010

Rancourt, D., Ahlich, E., Levine, J. A., Lee, M. S., & Schlauch, R. C. (2019). Applying a multidimensional model of craving to disordered eating behaviors: Development of the Food Approach and Avoidance Questionnaire. *Psychological Assessment*, *31*(6), 751-764. https://doi.org/10.1037/pas0000697

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of statistical software*, *48*, 1-36. https://doi.org/10.18637/jss.v048.i02

Sheldon, K. M., & Elliot, A. J. (1998). Not all personal goals are personal: Comparing autonomous and controlled reasons for goals as predictors of effort and attainment. *Personality and Social Psychology Bulletin*, *24*(5), 546-557. https://doi.org/10.1177/0146167298245010

Skvortsova, V., Palminteri, S., & Pessiglione, M. (2014). Learning to minimize efforts versus maximizing rewards: computational principles and neural correlates. *Journal of Neuroscience*, *34*(47), 15621-15630. https://doi.org/10.1523/JNEUROSCI.1350-14.2014

Steele, J. (2020). What is (perceived) effort? Objective and subjective effort during task performance. *PsyArχiv*. https://doi.org/10.31234/osf.io/kbyhm

Strasser, A., Luksys, G., Xin, L., Pessiglione, M., Gruetter, R., & Sandi, C. (2020). Glutamine-to-glutamate ratio in the nucleus accumbens predicts effort-based motivated performance in humans. *Neuropsychopharmacology*, *45*, 2048-2057. https://doi.org/10.1038/s41386-020-0760-6

Team, R. C. (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org. In.

Terwee, C. B., Bot, S. D., de Boer, M. R., van der Windt, D. A., Knol, D. L., Dekker, J., Bouter, L. M., & de Vet, H. C. (2007). Quality criteria were proposed for measurement properties of health status questionnaires. *Journal of Clinical Epidemiology*, *60*(1), 34-42. https://doi.org/10.1016/j.jclinepi.2006.03.012

Treadway, M. T., Buckholtz, J. W., Cowan, R. L., Woodward, N. D., Li, R., Ansari, M. S., Baldwin, R. M., Schwartzman, A. N., Kessler, R. M., & Zald, D. H. (2012). Dopaminergic mechanisms of individual differences in human effort-based decision-making. *Journal of Neuroscience*, *32*(18), 6170-6176. https://doi.org/10.1523/JNEUROSCI.6459-11.2012

Zénon, A., Sidibé, M., & Olivier, E. (2015). Disrupting the supplementary motor area makes physical effort appear less effortful. *Journal of Neuroscience*, *35*(23), 8737-8744. https://doi.org/10.1523/JNEUROSCI.3789-14.2015

Supplementary Material

Physical Effort Scale (PES) – Manual

Boris Cheval
Department of Sport Sciences and Physical Education
École normale supérieure de Rennes
boris.cheval@ens-rennes.fr
ORCID: 0000-0002-6236-4673

Silvio Maltagliati
Department of Biological Sciences
University of Southern California
silvio.maltagliati@univ-grenoble-alpes.fr
ORCID: 0000-0001-7199-0599

Delphine Courvoisier
Department of Medicine
University of Geneva
delphine.courvoisier@hcuge.ch
ORCID: 0000-0002-1956-2607

Samuele Marcora
Department of Biomedical and Neuromotor Sciences
University of Bologna
samuele.marcora@unibo.it
ORCID: 0000-0002-1570-7936

and

Matthieu Boisgontier
School of Rehabilitation Sciences
Faculty of Health Sciences
University of Ottawa
matthieu.boisgontier@uottawa.ca
ORCID: 0000-0001-9376-3071

Introduction

The Physical Effort Scale (PES) operationalizes the tendencies to approach and to avoid physical effort and provides the following information:

(1) Mean overall score to approach physical effort.
(2) Mean overall score to avoid physical effort.

Administration

The Physical Effort Scale can be administered in person or online. The questionnaire has been used with respondents 18 years of age and older. Participants indicate their level of agreement with each of the 8-items. They indicate their responses on a Likert scale anchored with (1) I completely disagree, (2) I disagree, (3) I neither agree nor disagree, (4) I agree, (5) I completely agree. The Physical Effort Scale takes approximately 2 minutes to complete.

Scoring

Calculation of a total mean score for the items belonging to the *Approach* dimension of the physical effort. A higher score indicates a greater tendency to approach physical effort.

Calculation of a total mean score for the items belonging to the *Avoidance* dimension of the physical effort. A higher score indicates a greater tendency to avoid physical effort.

Component	**Item Numbers**
Approach physical effort	1, 3, 6, 8
Avoid physical effort	2, 4, 5, 7

A relative tendency to approach rather than avoid physical effort can be computed as follows:

Relative tendency to approach physical effort = Average score for tendency to approach physical effort – Average score for tendency to avoid physical effort.

A higher score indicates a greater tendency to approach (rather than avoid) physical effort. This score is useful when researchers want to predict movement-based behaviors by simultaneously considering both the approach and the avoidance dimensions of physical effort.

Physical Effort Scale

<u>Instructions:</u> This questionnaire is about physical effort, which is usually associated with increased heart rate and breathing. Please read each of the following statements carefully and indicate the extent to which you agree or disagree with the statement. There are no right or wrong answers. Choose your response using the following scale:

I completely disagree (1)	I disagree (2)	I neither agree nor disagree (3)	I agree (4)	completely agree (5)

1.	I usually like activities that require physical effort.	1	2	3	4	5
2.	I tend to avoid situations in which I have to exert physical effort.	1	2	3	4	5
3.	The idea of exerting physical effort usually appeals to me.	1	2	3	4	5
4.	I tend to stay away from tasks that require physical effort.	1	2	3	4	5
5.	Exerting physical effort does not appeal to me.	1	2	3	4	5
6.	I generally enjoy activities that involve physical effort.	1	2	3	4	5
7.	I usually dislike activities that involve physical effort.	1	2	3	4	5
8.	I am usually willing to engage in activities that involve physical effort.	1	2	3	4	5

Reference

Cheval, B., Maltagliati, S., Courvoisier, D.S., Marcora, S., & Boisgontier, M. P. (2023). Development and validation of the Physical Effort Scale (PES).