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ORIGINAL PAPER

Different functions of physical effort in physical activity and sports: a scoping review of the value of physical effort

Johanna Stähler[1] · Maik Bieleke[1] · Wanja Wolff[2] · Julia Schüler[1]

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Abstract

Generally, effort is understood to be costly. Yet, it also is a generator of value, as it is instrumental for goal attainment but also because effort can be inherently rewarding and/or add value to outcomes. Research on effort's value-generating functions in sports and exercise seems surprisingly scarce, although they appear to be prototypical contexts. Here, we address this gap by first conceptualizing and then reviewing how physical effort's value-generating functions have been investigated in previous research. Attesting to the relative lack of research on this topic, an established machine-learning approach (*ASReview*) yielded 23 relevant papers out of an initial pool of 28,079 papers retrieved from four online databases. Consistent with theoretical assumptions, the reviewed papers showed that physical effort can be inherently rewarding and add value to outcomes. They offer insights into developmental differences in effort valuation and its neural correlates. However, they also reveal a relative inconsistency in how the valuation of effort generalizes across effort domains and highlight differences between measures of effort valuation. Further, although all included articles investigated physical effort's value, only six approached it in sports and exercise, and nine provided only indirect results. Taken together, this review supports the claim that physical effort can be valuable, it also highlights the demand for future research to close important gaps in the literature and identify underlying and moderating factors. We believe that sports and exercise research provides an ideal starting point for addressing these open questions and additionally benefits from such progress both conceptually and empirically.

Keywords Physical effort · Value of effort · Effort functions · Sport · Learned industriousness · Machine learning · Scoping review

Psychologists have been interested in effort for over a century (e.g., Bastian, 1887; Dewey, 1897; Ferrero, 1894; James, 1880; for a historical introduction, see Steele, 2021). Effort, as defined by Inzlicht et al. (2018) is 'the process that mediates between how well an organism can potentially perform on some task and how well they actually perform' (p. 338).

A particularly intriguing and surprisingly difficult question to answer is *why* people exert effort (e.g., Motivational Intensity Theory, Brehm & Self, 1989; neural and hormonal approaches, Proulx et al., 2018; Salamone & Correa, 2012; intrinsic motivation: Sheldon & Elliot, 1999).

Recently, it has been pointed out that effort serves not only one but various functions (Table 1) (Inzlicht et al., 2018). Probably the most intuitive and prototypical function is its use as an instrument to obtain a desired goal (*effort as instrument*). Here, effort is used as a means to an end: For instance, many people engage in physically effortful sports and exercises to increase their fitness or overall health. Importantly, people generally perceive effort as costly, which is highlighted by the fact that they tend to find its exertion aversive (e.g., Kurzban, 2016) and try to avoid it if possible (e.g., Brehm & Self, 1989; Gendolla et al., 2019; Hull, 1943). Thus, while effort is instrumental for successful goal attainment, its costs make it an instrument people use only to the degree justified by a potential reward (Brehm et al., 1983).

✉ Johanna Stähler
johanna.staehler@uni-konstanz.de

[1] Department of Sport Science, University of Konstanz, Universitätsstrasse 10, 78467 Constance, Germany

[2] Dynamics of Human Performance Regulation Laboratory, Department of Movement Science, University of Hamburg, Hamburg, Germany

Table 1 Overview of the three functions of physical effort

	Instrument	Reward	Value added
Definition	Effort is a costly instrument for successful goal attainment	Exerting effort is rewarding in itself, regardless of the outcome	A product gains value because effort was exerted to gain it
Example	When I go running, I intend to become fit	When I go running, I love to exert myself	When I go running, I like my body more due to my exerted effort
Exemplary theories/approaches	Motivational Intensity Theory, Achievement Goal Theory	Learned Industriousness	(Motoric) Sunk cost fallacy, Cognitive Dissonance Theory, Self-Perception Theory

In contrast, it has been highlighted that effort is also a generator of value: it can be inherently valuable (*effort as reward*) and add value to its outcome (*effort as value-added*) (Inzlicht et al., 2018). In these two functions, effort is not (only) perceived as costly and aversive but also as valuable and rewarding. Concerning *effort as reward*, people can like the exertion of effort, implying that activities demanding less effort are enjoyed less than activities requiring more effort (e.g., 'I climb mountains because it requires effort.'). Regarding *effort as value-added*, people can like an outcome *because* it requires effort (e.g., 'I love my toned body because I put so much effort into looking like this.'). Thus, while effort is a costly instrument in most cases, this might not be universally true, and even the opposite is possible: Effort can be valuable, even when it is not instrumental (e.g., continuing effortful training even when training effects are no longer expected). While most evidence for these additional functions of effort is scarce and largely comes from studies on cognitive effort (see Inzlicht et al., 2018), similar principles may apply to physical effort as well.

Cognitive and physical effort share conceptual similarities (Halperin & Vigotsky, 2023), and key theories of effort can often be applied across domains (e.g., Richter et al., 2016; Shenhav et al., 2013; Wolff et al., 2021). However, despite their conceptual overlap, cognitive and physical efforts are distinct in meaningful ways. For example, during physical effort, the neural reward systems may become more active (Cheval et al., 2018), and increased endocannabinoid concentrations reduce pain perception and enhance well-being during exercise (Dietrich & McDaniel, 2004). These neural and biological processes potentially help, making physical effort inherently rewarding, highlighting physical effort's unique aspects. This underscores the importance of investigating physical effort independently from cognitive effort.

As sport is defined as an activity needing physical effort (Cambridge Dictionary, n.d.), it is a promising domain to learn more about the value-generating functions of physical effort, and effort's different functions should be on vivid display (i.e., an instrument, a reward, and/or adding value): For people exercising as part of their New Years' resolution to lose weight, physical effort is a costly yet hopefully effective instrument to reach their goal. In contrast, for some athletes, exerting physical effort is what draws them to their sporting endeavors, irrespective of the tangible results this effort produces (Loewenstein, 1999).

These examples underscore that physical effort can serve different functions depending on the context and the individual. A comprehensive understanding of the factors influencing these functions is crucial for advancing our knowledge of the motivations underlying effort exertion as well as sports and exercise behaviors. In particular, understanding how physical effort can be inherently rewarding may help address the problem of physical inactivity by shifting the focus from instrumental effort outcomes to promoting the inherent value of physical effort itself (Maltagliati et al., 2024). Moreover, a deeper exploration of 'effort as adding value' could facilitate the effective application of external incentives designed to promote both the initiation of training and long-term motivation. Strategies that continuously emphasize previously exerted physical effort could enhance physical effort's perceived value, thereby making it easier for people to follow through with their New Years' resolution to get more fit. Ultimately, these insights could inform the development of interventions aimed at fostering sustained engagement in physical activity and contributing to healthier lifestyles.

Despite this relevance, until now, sports and physical activity literature has never explicitly conceptualized effort's different functions. Therefore, this review aims to close this gap by examining the extent to which sports and physical activity research already provides insights into the different functions of *physical effort*. Here, we are particularly interested in whether and how the value-generating functions of physical effort (*effort as a reward*, *effort as value added*) have been considered in previous research.

To achieve this goal, we proceed in two steps. In sport psychological research, theories of motivation are often used as conceptual underpinnings to explain the reason and amount of exerted physical effort (e.g., Bandura, 1977; Brehm & Self, 1989; Duda, 1987; Nicholls, 1984; Sheldon & Elliot, 1999; Weiner, 1972). While these theories readily acknowledge the essential role of physical effort, they do not explicitly distinguish between the distinct functions outlined above. Therefore, firstly, we evaluate current motivational theories with respect to the function(s) they ascribe to effort. In the second part, we perform a systematic literature search to examine the current state of knowledge concerning the value-generating functions of physical effort.

Efforts' functions in theories of human motivation

> Motivation determines the direction and *intensity* of behavior (Rheinberg, 2006, p. 13).

The latter refers to how much physical and cognitive effort one allocates toward a behavior (Biddle & Mutrie, 2008), making effort a key component of motivation and integral to many theories of human motivation (Steele, 2021). As theories differ in how they account for physical effort, we structured our review of motivational theories along the three functions of effort outlined above. To begin with, we briefly describe exemplary theories treating physical effort as a (costly) instrument and refer the reader to work investigating this instrumentality in the context of sports and exercise. As we focus on the value of physical effort, we then review the theorizing on physical effort as something inherently valuable, closing with theories and phenomena explaining how physical effort can add value.

Physical effort as an instrument

Many theories of human motivation emphasize the instrumentality of effort (e.g., Brehm & Self, 1989; Duda, 1987; Nicholls, 1984; Sarrazin et al., 2002). Moreover, substantial research efforts have aimed at uncovering the costs of effort exertion on the devaluation of rewards and on subsequent effort expenditure (e.g., effort discounting, Ostaszewski et al., 2013; Morel et al., 2017; ego depletion, Dang, 2018; Loschelder & Friese, 2016; mental fatigue, Boksem & Tops, 2008; Van Cutsem et al., 2017), how the willingness to use effort can be increased (e.g., extrinsic motivation, Chen et al., 2023; motive-based sport types, Lehnert et al., 2011; self-concordance, Sheldon & Elliot, 1999), how psychological interventions can reduce the costs of effort (e.g., Gollwitzer & Sheeran, 2006), and how effort is instrumental for success (e.g., Sarrazin et al., 2002). To illustrate how psychological theories account for effort as a costly yet useful instrument, we briefly summarize *Motivational Intensity Theory* (MIT) (Brehm & Self, 1989; in sports: Brinkmann et al., 2021) and *Achievement Goal Theory* (AGT) (Duda, 1987; Nicholls, 1984) as two prominent examples. We focus on these two theories because of their relevance to sports and exercise psychology and to provide an example of a domain-general theory (MIT) and a sport-specific theory (AGT) that both understand effort as an instrument (As this is only a selection of theories, we refer the interested reader to the overview by Steele, 2021).

MIT posits that people try to conserve resources (Brehm & Self, 1989). This is reflected in the fact that individuals choose the least effortful option to reach a goal and adjust effort expenditure according to the tasks' requirements (Brehm & Self, 1989): The higher/lower the task demand, the more/less effort is applied. However, when the task demands exceed the individual's abilities and success is perceived as impossible, motivation will drop, and any effort will be to no avail (Brehm & Self, 1989). Overall, MIT conceptualizes effort as an instrument, where the exertion of effort represents a cost that must be weighed against expected benefits.

AGT proposes two goal orientations in achievement situations in sports: task and ego orientation. These orientations differ in the beliefs about what leads to success (Fry & Fry, 1999) and thereby also regarding the function and value of effort. Task-oriented individuals feel successful when they improve their abilities through applied efforts (Van Yperen & Duda, 1999). For them, effort is an instrument to acquire skills and is valuable for growth and learning. In contrast, ego-oriented people compare their performance to that of others and feel successful when they outperform their peers, ideally with as little effort as possible (Van Yperen & Duda, 1999). They associate high effort with low ability (Fry & Fry, 1999), making effort an indicator of their abilities.

Although MIT and AGT differ in their specifics, both theories recognize physical effort as an instrument and agree that people do not use it excessively because its application is costly. Importantly, a substantial body of research has shown that MIT is a useful framework for understanding how people choose to employ physical effort as a costly but instrumental means of goal pursuit (Richter et al., 2016). Likewise, empirical work has repeatedly supported AGT's claim that task orientation makes people more likely to apply physical effort and perform well in various sports and exercise contexts (e.g., Sarrazin et al., 2002). Thus, the emphasis on effort as a costly instrument is well represented in psychological theorizing (Rigoli & Pezzulo, 2022), and its utilization as a costly instrument has received substantial attention. In contrast, only a few theories focus on the value of physical effort irrespective of its instrumentality (for an overview, see Table 1 in Inzlicht et al., 2018). In the following, some of these theories and phenomena will be reviewed.

Physical effort as a reward

Every year, millions of recreational athletes pay money to participate in exhausting endurance events (e.g., city marathons). For their efforts, they receive little tangible reward, which emphasizes that they rather pursue self-affirmation, social recognition, a feeling of self-efficacy, achievement motivation (setting and achieving high standards of excellence), and also because they enjoy the effort associated with training.

In the cognitive domain, the latter has long been established as the dispositional trait 'Need for Cognition', which describes the tendency to enjoy cognitive effort and seek out cognitively effortful activities (Cacioppo et al., 1996; Cacioppo & Petty, 1982). To illustrate, people with a high 'Need for Cognition' tend to do more cognitively effortful leisure activities like reading newspapers or practicing the cello (Therriault et al., 2015) compared to people scoring low on this trait. A similar concept may apply to the physical domain, where individuals who value physical effort tend to be more physically active and exercise more (Bieleke et al., 2023). This comparison suggests a potential parallel between cognitive and physical effort valuation, and empirical research, such as the work by Bieleke et al. (2023), supports this idea in the context of physical activity.

The theory of *Learned Industriousness* is a theory that explains how this trait is developed and how effort can become valued through the lens of reinforcement learning (Eisenberger, 1992). Initially, effort might be understood and applied as an instrument to reach certain goals. However, when effort is repeatedly paired with a primary reinforcer (e.g., money, praise), it will assume characteristics of a secondary reinforcer. As per the principles of reinforcement learning, effort itself becomes rewarding over time, and its exertion does not depend on the presence of a primary reinforcer anymore. Importantly, if effort has turned into a secondary reinforcer, the theory proposes that it generalizes across behaviors and between domains (i.e., cognitive and physical). Thus, 'learning to like effort' suggests that individuals who develop a preference for effort are generally more inclined to engage in effortful activities. For instance, it has been proposed that individuals with anorexia nervosa, who engage in effortful behaviors like exercise and restrictive eating, may exhibit reduced sensitivity to the costs of effort or even perceive effort itself as rewarding, a phenomenon that could potentially be explained by the process of Learned Industriousness (Haynos et al., 2022). While the theory of Learned Industriousness has predominantly been studied in animals, empirical investigations in humans—particularly in the physical domain—remain limited. Nevertheless, given the fundamental nature of the underlying learning principle, it is plausible to expect similar results in humans (see e.g., Clay et al., 2022; Lin et al., 2024).

In the context of physical effort, this mechanism potentially is further amplified through the release of endogenous lipid-derived signaling molecules during intense physical activity (Dietrich & McDaniel, 2004). In contrast to the cognitive domain, physical exertion leads to the release of endocannabinoids, which have inherent rewarding effects by reducing pain perception and enhancing well-being. The repeated experience that intense physical effort positively impacts well-being—not just by aiding in the attainment of external goals—suggests that this learning process may occur more rapidly with physical effort than with cognitive effort. However, this remains an empirical question yet to be fully resolved.

Taken together, physical effort as a reward might be the physical equivalent of the 'Need for Cognition' and the theory of Learned Industriousness offers a sound explanation for how and why effort can become less costly and even inherently valuable. Importantly, by embedding this explanation into the mechanisms that underlie reinforcement learning, the theory provides starting points for interventions that could help people value effort more and, in turn, lead a physically more active life. However, research on sports and exercise psychology has only scarcely utilized this framework to understand sports and physical activity behavior, and, to our best knowledge, no reviews on the inherent value of physical effort in sports and physical activity have been published so far.

Physical effort as value-added

The late soccer great Pelè is quoted as stating, 'The more difficult the victory, the greater the joy of victory.' In other words: The greater the costs or, more specifically, the greater the applied effort, the more valuable the attained outcome. This suggests that beyond being a costly necessity or inherently valuable, effort can enhance the perceived value of an outcome. This idea is supported by the IKEA effect, which refers to the phenomenon where products are liked more when individuals have to exert effort to create or obtain them (Norton et al., 2012). Similarly, a real-life example of effort enhancing value is seen in competitions. Consider a race scenario, where you compete against less skilled opponents and secure a win with only moderate effort. Victory will probably feel rewarding, but not as sweet as if you had just beaten an equally skilled competitor where you had to push yourself to your limit to secure a win. This dynamic highlights how effort can enhance the perceived value of an outcome.

At least two psychological theories explain how exerted effort can increase the value of an outcome: *Cognitive Dissonance Theory* (Festinger, 1957) suggests that when individuals experience a mismatch between their beliefs and behavior, they seek to minimize this cognitive dissonance. When a person exerts high effort for a seemingly low-value outcome, they may assign additional value to the result to 'justify' the effort exerted. *Self-Perception Theory* (Bem, 1972) assumes that not the internal perception of effort or arousal but the external observation of one's (own) overt behavior leads to this attitude change. Despite differences in these theoretical explanations, both theories suggest that people increase the perceived value of an outcome when significant effort is exerted.

Additionally, several well-known cognitive biases and fallacies reflect this principle (for a more comprehensive list, see Table 1 in Inzlicht et al., 2018). For example, the *(Motor) Sunk Cost Fallacy* states that individuals are more likely to continue exerting (physical) effort the more effort they have already invested (Kacelnik & Marsh, 2002). From the perspective of physical effort adding value, this behavior can be explained by the notion that previously exerted effort has enhanced the outcome's value, making it seem worthwhile to continue exerting further effort to achieve it (Other possible explanations may include that the reward has not yet been obtained, the goal is not yet achieved, or negative consequences are being avoided). Moreover, research has demonstrated that individuals often prefer rewards obtained through greater effort over those gained with minimal effort, even when the rewards themselves are identical (Kacelnik & Marsh, 2002).

In sum, in the aforementioned theories and fallacies, effort is experienced as aversive, and due to this costliness, applying effort adds value to an outcome. However, research that has investigated this in the sports and physical activity context is scarce, and no reviews on how physical effort can enhance the value of an outcome have been published so far in the context of sports and physical activity.

The present research

In the present work, we address a theoretical gap by conducting a first review of published research on the value of physical effort (*effort as reward; effort as value-added*) in the context of sports and physical activity. Given the limited existing research in this area, we chose to conduct a scoping review, to provide a comprehensive overview of the scope and nature of current articles, serving as a starting point for future research. Importantly, the value of physical effort is rarely explicitly investigated in sport psychology, and the available evidence is scattered across different disciplines. Hence, we utilized a broad set of keywords spanning various disciplines. To be able to screen a vast body of papers and minimize the risk of missing relevant ones, we employed an established machine learning approach that allows for the efficient review of large amounts of papers based on training data (AS Review, https://asreview.nl/).

Method

We developed a search protocol in the spring of 2021 and conducted a literature search to identify all articles concerning physical effort *as a reward* and *adding value* to an outcome in sports, physical activity, and physical education. This search was based on the scoping review framework suggested by Arksey & O'Malley (Arksey & O'Malley, 2005) and the PRISMA guidelines for scoping reviews (PRISMA-ScR; Tricco et al., 2018; freely accessible https://www.prisma-statement.org/scoping). The filled-in PRISMA checklist is available in OSF (osf.io/yjzdt).

Eligibility criteria

We conducted a search for peer-reviewed research published in English that investigates the valuation of physical effort or physical effort's outcome. As is common in scoping reviews (Arksey & O'Malley, 2005), and due to the anticipated scarcity of articles, our selection criteria for this scoping review were intentionally less restrictive to encompass a broad range of studies, thereby incorporating diverse approaches and perspectives. We aim to summarize the scope and nature of current research. Thus, all kinds of articles (e.g., theoretical articles or empirical studies) were eligible for this review. In empirical studies, the method used to measure the valuation of physical effort (e.g., effort expenditure or questionnaire application) was not decisive. Only studies involving human participants were deemed relevant, as our focus was on examining the value of effort in sports and exercise, a consideration that cannot be adequately explored using animal subjects. Additionally, papers were excluded if they were not from the physical domain or did not address the value of physical effort or its outcome. No additional restrictions were applied, for example, regarding the year of publication.

Information sources and search

The search was carried out on March 31 and April 1, 2021, and was updated on November 23, 2023 (see Fig. 1 for the PRISMA flow chart). Given the absence of specific keywords for the phenomena we are investigating, using a few

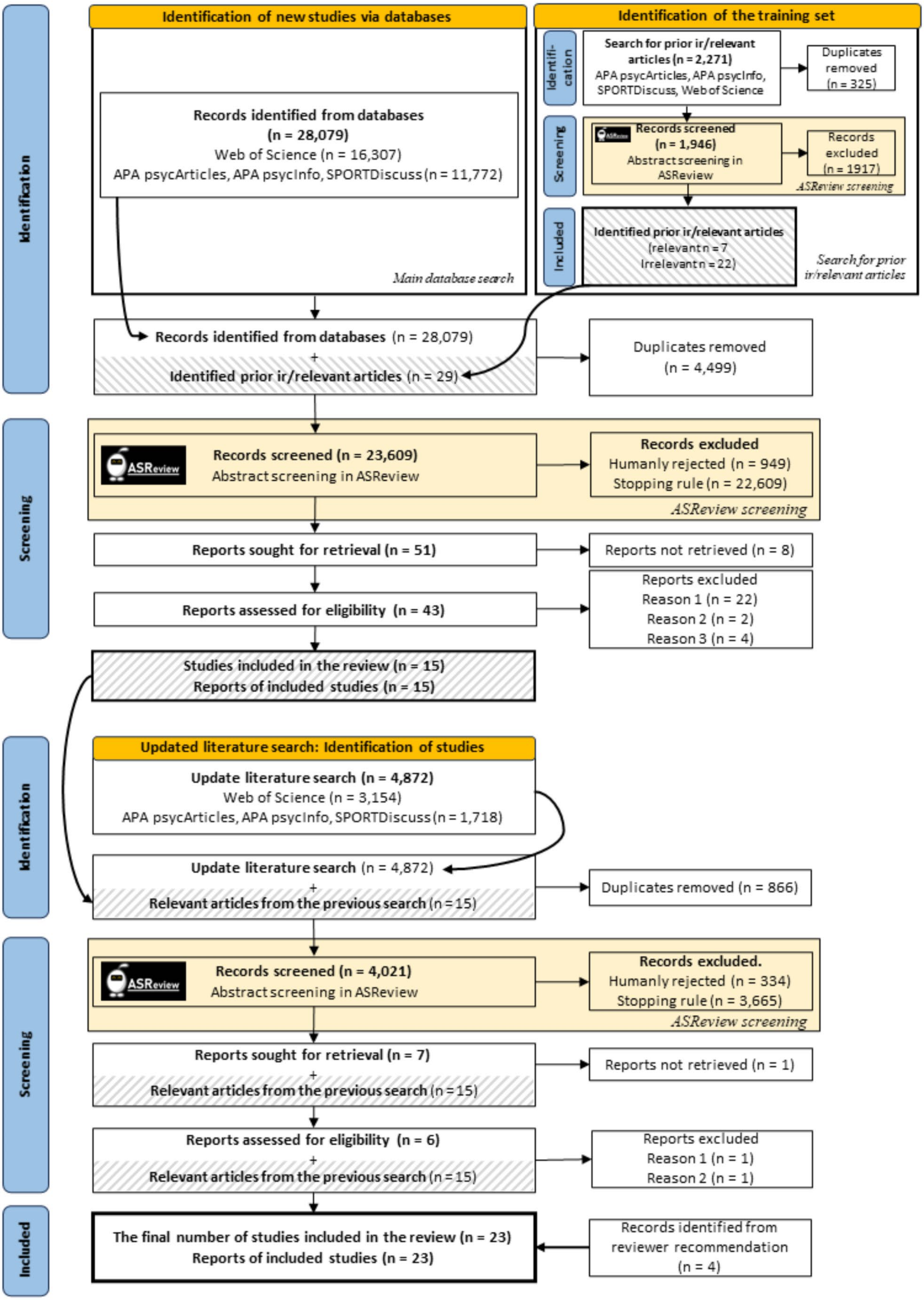
Identification
Identification of new studies via databases
Records identified from databases
(n = 28,079)
Web of Science (n = 16,307)
APA psycArticles, APA psycInfo, SPORTDiscuss (n = 11,772)
Main database search
Identification of the training set
Identifi-cation
Search for prior ir/relevant articles (n = 2,271)
APA psycArticles, APA psycInfo, SPORTDiscuss, Web of Science
Duplicates removed (n = 325)
Screening
Records screened (n = 1,946)
Abstract screening in ASReview
Records excluded (n = 1917)
ASReview screening
Included
Identified prior ir/relevant articles
(relevant n = 7
Irrelevant n = 22)
Search for prior ir/relevant articles
Records identified from databases (n = 28,079)
+
Identified prior ir/relevant articles (n = 29)
Duplicates removed
(n = 4,499)
Screening
ASReview
Records screened (n = 23,609)
Abstract screening in ASReview
Records excluded
Humanly rejected (n = 949)
Stopping rule (n = 22,609)
ASReview screening
Reports sought for retrieval (n = 51)
Reports not retrieved (n = 8)
Reports assessed for eligibility (n = 43)
Reports excluded
Reason 1 (n = 22)
Reason 2 (n = 2)
Reason 3 (n = 4)
Studies included in the review (n = 15)
Reports of included studies (n = 15)
Identification
Updated literature search: Identification of studies
Update literature search (n = 4,872)
Web of Science (n = 3,154)
APA psycArticles, APA psycInfo, SPORTDiscuss (n = 1,718)
Update literature search (n = 4,872)
+
Relevant articles from the previous search (n = 15)
Duplicates removed (n = 866)
Screening
ASReview
Records screened (n = 4,021)
Abstract screening in ASReview
Records excluded.
Humanly rejected (n = 334)
Stopping rule (n = 3,665)
ASReview screening
Reports sought for retrieval (n = 7)
+
Relevant articles from the previous search (n = 15)
Reports not retrieved (n = 1)
Reports assessed for eligibility (n = 6)
+
Relevant articles from the previous search (n = 15)
Reports excluded
Reason 1 (n = 1)
Reason 2 (n = 1)
Included
The final number of studies included in the review (n = 23)
Reports of included studies (n = 23)
Records identified from reviewer recommendation
(n = 4)

Fig. 1 PRISMA flow chart, enhanced by the integration of ASReview, illustrates the literature search for this scoping review. Note. Reason 1 = Articles do not investigate the value of effort or its outcomes' value. Reason 2 = Not about physical effort. Reason 3 = Animal study. Template from: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ2021;372:n71.doi:https://doi.org/10.1136/bmj.n71

narrow search terms seems unsuitable. Thus, we conducted a comprehensive keyword search to avoid missing relevant articles, considering the anticipated scarcity of existing literature on the subject.

We searched four databases (Web of Science: Web of Science interface, 31.03.2021; APA PsycArticles: EBSCO interface, APA PsycInfo: EBSCO interface, and SPORTDiscus: EBSCO interface, 01.04.2021; Fig. 1: 'Identification of studies').[1] The authors jointly developed the following search string for the main database search: 'physical effort' OR (athlete AND effort) OR (exerciser AND effort) OR ('physical activity' AND effort) OR ('physical education' AND effort). In this way, three areas of sports psychology were covered: performance, physical activity, and physical education.

Selection of sources of evidence

Active learning for systematic reviews

We employed the open-source reviewing software ASReview (https://asreview.nl/) to screen the expected wealth of abstracts systematically, efficiently, and transparently while reducing human bias. ASReview applies active learning techniques to optimize the abstract screening process for reviewing large bodies of literature (van de Schoot et al., 2021). It has already been utilized in several systematic and scoping reviews across diverse domains, including physical activity (Feil et al., 2023), neuroimaging (Warren & Moustafa, 2023), and sport psychology (Ekelund et al., 2023). For abstract screening, the pool of articles retrieved from the literature search must be added to ASReview. Then, prior knowledge (training set) must be indicated by labeling articles as relevant or irrelevant to train the first active learning algorithm. Subsequently, the active learning cycle starts: Based on the training set, ASReview presents abstracts to the reviewer to classify as relevant or irrelevant. From each decision, the active learning algorithm learns and improves its suggestions (for more information, see https://asreview.readthedocs.io/en/latest/guides/activelearning.html). This process helps the reviewer to find relevant articles relatively early in the screening process, reducing the need to screen all articles. (Find the description of our proceeding to identify the training set and the list of articles included in the training set in the OSF: https://osf.io/yjzdt)

Abstract screening in ASReview

The main literature search yielded 28,079 articles to which the training set of 29 articles has been added (one irrelevant and one relevant article would be sufficient; see https://asreview.readthedocs.io). Of these, 4499 duplicates were manually removed using Citavi. Then the remaining 23,580 abstracts (training set and main search) were screened in ASReview. The training set was used as prior knowledge to train the first machine-learning model. We chose a naïve bayesian text classifier, which assumes (conditional) independence for the features, and tf-idf as a feature extraction strategy (Ferdinands et al., 2020). Tf-idf is a bag-of-words method, considering how frequently words occur in articles. Accordingly, when a word occurs scarcely, it differentiates well between papers. We selected these settings for our active learning model as they have proven reliable (Ferdinands et al., 2020). Additionally, we used a mixed query strategy, as it combines proposing the most relevant article and choosing a random article. Since our articles come from different research domains, random choices are essential for suggestions from more than one domain. Additionally, we defined the stopping rule (https://asreview.nl/asreview-class-101/) for the abstract screening, wherein our active learning cycle continued until two hundred consecutive articles were considered irrelevant (Callaghan & Müller-Hansen, 2020).

Data charting process and data items

Our data-charting form was developed by the first author and interactively refined by all authors. Also, the first author did the first data charting and discussed it with the other authors. Changes and improvements were made in an iterative process. First, we grouped the articles by whether they measured effort's or its outcome's value. We charted the articles after the following information (Table 2): author(s) and year of publication, sample size, and sample characteristics, the measured independent and dependent variables, a short study description, and the main findings. Further, we indicated whether the research question was directly about effort's or effort's outcome's value (direct) or whether it was

[1] We updated our literature search in the same databases with the same search string in November 2023 to add the most recent articles. The search yielded 4,872 articles (removing 866 duplicates in Zotero), whose abstracts were screened in ASReview. We used the 15 articles (plus the four animal studies) found in the first main search as a training set (see SI. 2 in OSF). The same settings were used for ASReview as in the first screening. In addition, due to a newer ASReview version, the balancing had to be specified where we use a 'Data rebalancing strategy', which helps for imbalanced datasets with few inclusions and many exclusions as our search.

indirect evidence. Lastly, we indicated whether the research was from the sports and exercise context (yes/no).

Results

Figure 1 illustrates the literature search flow. After abstract screening, 51 articles were considered relevant. However, eight could not be retrieved, 22 did not investigate effort's value-generating functions, one did not investigate physical effort, and four had animal subjects. Thus, 16 articles were included in this review. An update of the literature search identified another seven publications for retrieval but one could not be retrieved and two articles turned out to be irrelevant for this review. Another four articles were identified as relevant during the peer-review process. In total, 23 publications were included in this review (inclusive the theoretical artical by Inzlicht et al. (2018).

Results are structured in two parts—first, we summarized literature that addresses *physical effort as a reward* ($n = 12$), and second, we summarized studies regarding *physical effort adding value* ($n = 10$). For both parts, different general topics and approaches emerged around the evidence pertaining directly to the functions of effort. Roughly, in the first part these pertained to (1) generalization across domains, (2) developmental aspects, (3) neural correlates, and (4) different measurement approaches. For the second part, results are structured regarding (1) developmental aspects, (2) neural correlates, and (3) different measurement approaches. We discussed the findings along these topics and approaches in turn.

Effort function: physical effort as a reward

Three studies directly investigated whether and how physical effort gains value and eventually can become a reward. Another nine studies are considered indirect evidence as they measured the value of effort but either did not investigate it as the construct of main interest ($n = 4$) or conceptualized it as costly instead of rewarding ($n = 5$) (Table 2—*direct evidence*). However, the results of these studies add to the knowledge about when and how physical effort becomes a reward and thus are included in this review. Furthermore, although all articles investigated physical effort, six studies did so in sports and exercise, whereas the other six used physical effort paradigms (e.g., finger tapping; Table 2—*Sport*).

Evidence that physical effort is rewarding

A series of experiments found that participants frequently exerted more physical effort than required, although no additional rewards were offered for doing so (Stanek & Richter, 2021). These results are particularly interesting as the studies were based on MIT yet they appear to contradict its foundational assumptions. In fact, they can even be interpreted as indirect evidence for physical effort being a reward, prompting participants to exert effort beyond what would be justified by a cost-benefit analysis that relies purely on efforts' instrumentality. Naturally, alternative explanations for these findings must be considered, and further investigation is warranted to explore the underlying mechanisms at play.

Furthermore, a questionnaire study offers essential insights about valuing physical effort: Individuals perceiving themselves as more capable (greater physical self-efficacy) exert more effort in sports and have a greater enjoyment of the physical effort (or vice versa) (Wright et al., 2005). Thus, people more comfortable with exercise are more likely to derive greater enjoyment from it and to experience physical effort as rewarding.

Direct evidence comes from a study investigating the mechanism of effort becoming rewarding (Bernacer et al., 2019). Participants were assigned either to an exercise or a control group. Frequent training resulted in a diminished influence of effort costs on decisions, evident in an effort-discounting task following the training phase (Bernacer et al., 2019). Interestingly, exerting effort was not reinforced through external rewards, indicating that physical effort gained value just by occupying more opportunities to apply it.

Generalization of effort

Four studies yield direct (Bustamante et al., 2014) or indirect (Chong et al., 2018; Jonker et al., 2010; Toering et al., 2009) evidence about the generalization of the value of effort across physical and cognitive domains.

Bustamante et al. (2014) studied whether industriousness learned in a (high/low effort) physical or cognitive task would generalize to a subsequent cognitive task. The high and low cognitive effort groups showed no difference, whereas the low physical effort group was more persistent in the subsequent cognitive task than the high physical effort group. The authors concluded that either no generalization of industriousness from the physical to the cognitive domain occurred or that the consequences of intense physical activity covered it. Specifically, the participants may have been so fatigued from the physical exertion that they required time to recover before they could fully engage with the cognitive task, preventing any potential transfer of industriousness from being observed.

Also, the indirect evidence provides ambiguous results. A correlational study showed that elite youth athletes achieve both higher educational levels and greater athletic success

Table 2 Overview of studies included in this review

Study	Sample size and characteristics	Independent variables	Dependent variables	Study description	Results	Direct evidence[a]	Sport[b]
Physical effort as a reward							
Bernacer et al. (2019)	24 sedentary humans (M=20 years; 14 female)	3-month fitness program vs. no program	Choices in effort-discounting tasks; Brain activation	Participants were brain scanned and completed effort- and risk-discounting decision-making tasks before and after accomplishing a 3-month fitness program	After the training, participants showed reduced effort costs on decisions and changes in brain connectivity between the amygdala and anterior cingulate cortex	✓	✓
Bustamante et al. (2014)	80 inactive humans (M=23 years; 56 female)	Effort training (2 × 2): low vs. high, physical vs. cognitive	Preference for (cognitive) effort via persistence in a cognitive task	After a baseline measure of the persistence in a cognitive task, participants received group-specific effort training, and again the persistence in the cognitive task was measured	Post-training the low (vs. high) physical effort group was more persistent in the cognitive task. The other groups did not differ in persistence. Thus, no generalization of industriousness from physical to cognitive domains was found, or the consequences of intense physical activity covered it	✓	✓
Chong et al. (2018)	20 elite rowers and 20 matched non-athletic controls (M=23; 23 female)	Physical and cognitive task; Athlete vs. non-athlete	Choice: low-effort/low-reward vs. higher-effort/higher-reward	Participants were trained in cognitive and physical tasks. Then the decision-making period started: choices between a low-effort/-reward and high-effort/-reward option regarding either the cognitive or physical task	Athletes preferred high physical effort compared to non-athletes. Computationally modeled effort discounting patterns showed no difference between effort domains for athletes: The reward devaluation increased with increasing effort. Non-athletes showed a similar pattern for the physical but a reversed one for the cognitive task	X	✓
Jonker et al. (2010)	292 students (M=14 years; all male)	Athletic level: Elite youth soccer players vs. typical students	Self-regulatory skills: planning, self-monitoring, evaluation, reflection, and effort	Participants filled in questionnaires. The effort subscale of the scale to measure self-regulatory skills measured the willingness to invest effort (e.g., 'even if I don't like the task' Hong et al., 1999, p. 194)	Elite youth athletes scored higher on the effort subscale and had higher education levels than non-athletes. A higher willingness to exert effort was associated with higher achievements, both in academia and sports	X	✓

Table 2 (continued)

Study	Sample size and characteristics	Independent variables	Dependent variables	Study description	Results	Direct evidence[a]	Sport[b]
Rodman et al. (2021)	103 adolescents and young adults (M = 18; 48 female)	Age: Adolescents vs. young adults; Effort: high vs. low; Reward: high vs. low	Effort exertion: peak grip force & speed; Strategic optimization of effort (e.g., rate of trial non-completion)	The demanded grip force and the amount of monetary reward were presented on the screen. Participants exerted grip force with the hand dynamometer. Success was indicated when they accomplished the required force, and participants were rewarded.	While adolescents often invested more effort than required, young adults strategically prepared for the effort exertion and made effort-saving choices (e.g., opting out of low-reward trials)	X	X
Stanek and Richter (2021)	5 Studies: N = 114 (M = 23; 87 female)	(2 × 2) Task difficulty: low/high; Reward value: low/high	Energy investment: Exerted muscle force in hand grip task	First task: Exerting required grip force as precisely as possible. Second task: (ketchup task) Demanded force and reward level is presented. Participants had the opportunity to exert effort to receive the reward	In all 5 studies, participants exerted more effort than required in the low-effort condition	X	X
Sullivan-Toole et al. (2019)	23 adolescents (M = 15 years; 13 female) and 25 young adults (M = 20 years; 14 female)	Age: Adolescents vs. young adults	Blaster choice: four effort levels (number of button presses) and three reward levels; Blaster liking	The study was presented as a game. In each trial, one of two blasters was chosen and had to be charged with button presses depending on its effort demand. Success: demand met and chosen blaster strong enough. Loss: effort demand unmet, or blaster not strong enough. Blaster liking was measured before and after the game	'Whereas adults consistently preferred lower-effort options within each reward level (…), adolescent preferences only differentiated between the high and extreme effort levels. (…) adolescents exhibit less sensitivity to effort costs than adults (…)' (p. 5)	X	X

Table 2 (continued)

Study	Sample size and characteristics	Independent variables	Dependent variables	Study description	Results	Direct evidence[a]	Sport[b]
Toering et al. (2009)	444 youth soccer players (M=14 years; all male)	Athletic level: Elite vs. non-elite youth soccer players	Self-regulation (effort, planning, evaluation, reflection, self-efficacy)	Participants filled in all the questionnaires	Willingness to exert effort was associated with sports performance level. High effort scores indicated a greater chance of players belonging to the elite group. Elite players reported to invest more effort into executing tasks than non-elite players, indicating that elite players tend to try harder to succeed	X	✓
Toro-Serey et al. (2022)	84 humans (M=21; 58 female)	Costs: cogntive effort, low/high physical effort, or waiting time; Rewards: 4, 8, 20 ct.	Accepting or rejecting a task	Participants decided whether they wanted to gain a shown monetary reward. Then they got to know the costs and had to invest effort or passive waiting time to earn the reward	Greater preference for cognitive effort when people face a single form of demand (over physical effort and doing nothing) but faded over time when other options were available. Participants did not always choose effort over doing nothing	✓	X
Umesh et al. (2020)	24 humans (M=23 years; 12 female)	Correlational: Anatomical proportions of the hand knobs' brain area	Effort choice; Anatomical properties: brain area of the hand knob	Structural brain scans were measured using magnetic resonance imaging. Then an effort-based decision-making task was conducted. Participants chose between two grip force options: little but sure effort vs. 'risky option that could result in even more grip exertion or none at all' (p. 2373)	Participants with a greater cortical thickness of hand knob found grip force effort costlier. Effort increases are more aversive for higher than lower effort	X	X
Van Yperen et al. (2021)	146 student-athletes (M = 14 years; 60 female)	Effort domain: school or sports	effort expenditure; need for competence; effort attribution	Participants filled in all the questionnaires	Student-athletes' need for competence and willingness to exert effort was higher in the sports than in the school domain. The need for competence in each domain is related to the domain-specific willingness to invest effort	X	✓

Table 2 (continued)

Study	Sample size and characteristics	Independent variables	Dependent variables	Study description	Results	Direct evidence[a]	Sport[b]
Wright et al. (2005)	46 minority adolescents (M = 15 years; 27 female)	Physical self-efficacy	Effort (e.g., 'I try hard in physical activity'); enjoyment (e.g., 'I usually have fun in physical activity'); perceived physical ability	Participants filled in all the questionnaires	Effort and enjoyment of effort were positively associated with perceived self-efficacy and physical activity. Perceived physical ability explains unique variance in effort and enjoyment	X	X
Physical effort as value-added							
Alessandri et al. (2008b)	42 children (7–8 years; 18 female)	High or low effort (7 mouse clicks for high, 1 click for low effort)	Preference of effort outcome: Choice between high- vs. low-effort shape	Training phase: Shapes were associated with high or low effort. If the required effort was met, a reinforcer was presented. Test phase: The preference for the high- and low-effort shapes was measured	The children showed a significant preference for shapes associated with high effort compared to low-effort shapes	✓	X
Alessandri et al. (2008a)	30 students (20 female)	High and low effort (grip force); time to start task: 1 vs. 5 s.	Preference for effort outcome: Choice between the high- vs. low-effort stimuli	The preference for high vs. low effort was measured by asking to apply different amounts of force over different durations. The participants had to press on a force cell with either high or low effort for 1–5 s. After training, they could choose between these tasks	Generally, low-effort tasks were preferred. However, the high-effort stimulus was preferred over the low-effort stimulus. Specifically, most participants chose low-effort, short-duration tasks when given a choice, but favored the stimulus linked to the higher effort and longer duration tasks	✓	X
Jiang and Zheng (2023)	32 young adults (M=20 years; 16 female)	Effort type: physical/cognitive; Difficulty: high/low; Feedback: positive/negative	Brain activation (EEG)	Participants performed an effortful task (effort phase; physical/cognitive). In the following rewarding phase, participants played a gambling game to earn money and received feedback on whether their effort resulted in success	Exertion of effort led to decreased brain activation in the subsequent feedback evaluation. This effect was independent of effort type for the early phase of evaluation but domain-specific for later phases	✓	X

Table 2 (continued)

Study	Sample size and characteristics	Independent variables	Dependent variables	Study description	Results	Direct evidence[a]	Sport[b]
Kiefer et al. (2023)	130 5- to7-year-olds ($M=6$; 67 female)	Task: cognitive/ physical; difficulty: hard/ easy	Toy's value: willingness to pay for a toy; choose between directly watching a video with a stranger's toy or waiting to watch a video with the own toy; Waiting time to watch the video	The children built their toys by playing cognitive/ physical easy/ hard games. Then their toy's value was queried using several methods	The own toy is worth more coins than a stranger's toy, independent of task and difficulty. Children in the cognitive effort condition were more likely to wait for their toy than those in the physical condition. Older children, children in the cognitive condition, and children in the low-effort condition were more likely to wait for the full test trial	✓	X
Klein et al. (2005)	32 students (25 female)	High or low effort (20 or 30 mouse clicks for high, 1 click for low effort)	Preference of effort outcome: Choice between high- vs. low-effort stimuli	The preference for high vs. low effort was measured by having the participants choose between two stimuli after different levels of effort. They then chose between stimuli associated with either high or low effort in a test phase. The preference for the stimuli was measured	When participants exerted physical effort to obtain two different positive stimuli, they showed a preference for the one that required more effort compared to the one that required less effort	✓	X
Lewis (1964)	110 boys (52 first and 58 sixth graders)	High or low effort (18 turns of crank handle with break vs. 3 turns without break)	Preference of effort outcome: keep or change chips	The children were given chips in one color as a reward for effort exertion. Then they had the opportunity to exchange them for different colored chips. Subsequently, the children had to choose between two levers, which had a different reward rate. Pressing the correct lever, gave them a reward chip in the same color as before	No significant difference in the number of chips the children were willing to exchange, regardless of effort and age. First graders who had to exert greater effort performed significantly better in the lever-pressing task than those exerting low effort. They chose the correct lever more often, indicating that the reward was more valuable to them. Sixth graders do not show this effect	✓	X

Table 2 (continued)

Study	Sample size and characteristics	Independent variables	Dependent variables	Study description	Results	Direct evidence[a]	Sport[b]
Palidis and Gribble (2020)	18 healthy humans (*M*=22; 9 female)	High or low effort demanded of the quadriceps	Reward Processing: Brain activation (mid-frontal EEG); Preference for effort outcome: choice	Participants chose between two options and then had to provide a demanded muscle tension (high or low effort). After each trial, they got feedback on their accuracy of muscle activation	The high physical effort resulted in an increased response to the feedback. Indicating that effort was not treated as a loss but affected the evaluation of reinforcement outcomes	✓	X
Turner et al. (2021)	42 humans (*M*=24)	Demanded effort to report a decision (low, medium, high)	Confidence in the decision (decision=result of effort investment)	Participants pressed a grip-force dynamometer to indicate which of two lights was brighter. Afterward, they rated their confidence in their decision	Greater effort to report a decision led to more confidence in the correctness of choice	✓	X
Vinckier et al. (2019)	66 humans (*M*=24 years; 45 female)	Choice: apply effort or not; Effort: amount of physical effort; Success: was the item obtained	Rating: liking of food items; Subsequent choice; Effort, and Success	Participants rated how much they wanted to eat a food item. Then they had the opportunity to apply effort to obtain the item. Then the rating and effort expenditure tasks were repeated. The experiment closed with a final rating of the liking of the food items	Effort investment caused changes in the valuation of the food item, which affected subsequent ratings of the product, choices, and action outcomes	✓	X
Wu and Zheng (2023)	40 humans (*M*=21; 20 female)	Physical effort; perceived control: active/passive choices	Reward processing: brain activation (EEG)	Effort-reward task: The participants exerted varying levels of physical effort to win monetary rewards by active or passive decision-making	Effort discounting effect for an early phase in reward processing (reward positivity period). Whereas during the late positive potential interval effort had an effort enhancement effect. The more effort was discounted in the first phase, the more was enhanced in the later phase	✓	X

The first section shows the results for 'Physical effort as a reward', and the second section for 'Physical effort as value added'

Inzlicht et al. (2018) are not listed here as it is a theoretical article introducing the effort paradox but not an empirical study

[a]Direct evidence = Main research question about the value of physical effort?

[b]Sports = Is the article from the sports or exercise domain?

than non-athletes, which was related to their greater 'willingness to exert effort' (Jonker et al., 2010). In contrast, another study found athletes to have a higher preference for high physical effort compared to non-athletes but no differences in cognitive effort (Chong et al., 2018). Comparing computationally modeled effort discounting patterns between athletes and non-athletes and between cognitive and physical effort showed no differences between groups for physical effort, whereas the discounting patterns for cognitive effort were distinct for each group (Chong et al., 2018).

In summary, evidence regarding the generalization of efforts' value between domains is inconsistent. Indeed, people successful in sports and academia tend to value effort exertion generally (Jonker et al., 2010). However, people willing to exert effort in one domain do not necessarily prefer effort in other domains as well (Chong et al., 2018). Also, the relationship of effort costs between domains and between athletes and non-athletes is more complex (Chong et al., 2018). This might explain why the generalization of industriousness did not happen within one short training session (Bustamante et al., 2014).

Developmental aspects

Willingness to apply effort differs as a function of age (Rodman et al., 2021; Sullivan-Toole et al., 2019). Two studies investigated whether there are differences in physical effort expenditure between adolescents and adults (Rodman et al., 2021; Sullivan-Toole et al., 2019). The results of both studies correspond and show that adolescents are less sensitive to effort costs than adults. Adolescents' choices were less influenced by the task requirements, and thus, they tended to invest more physical effort than needed, especially in low-reward trials (Sullivan-Toole et al., 2019). In contrast, adults approached the tasks more strategically and saved energy, for example, by dropping out in low-reward trials (Rodman et al., 2021). Taken together, these studies indicate that adolescence might be a sensitive developmental phase where physical effort allocation is less strongly coupled with prospective rewards.

Neural correlates

Two studies examined the neural correlates of the value of physical effort (Bernacer et al., 2019; Umesh et al., 2020). Regularly exerting physical effort led to neural changes in sedentary individuals, indicating a reduced influence of effort costs on behavior (Bernacer et al., 2019). More precisely, after regular training, effort-cost-signals decreased in the anterior cingulate cortex (ACC)—a structure that has been implicated in effort-discounting (Chong et al., 2017). Additionally, the functional connectivity between ACC and the amygdala increased, especially during high-effort choices. This connectivity is important for investing more effort to gain greater rewards (Floresco & Ghods-Sharifi, 2007). Lastly, before regular training, a higher nucleus accumbens activation was observed for secure effortless rewards, indicating their greater value compared to the effortful option. However, after the fitness plan, this distinction diminished, indicating a reduction in effort costs (Bernacer et al., 2019).

In a cross-sectional study, it was found that greater motor cortical thickness is associated with less preference for and a greater costliness of effort (Umesh et al., 2020). Motor cortical thickness increases with physical training (Anderson et al., 2002) and is related to resting motor thresholds (List et al., 2013). Correspondingly, regular physical training is associated with an enlarged motor cortex and finding a prospective effort costlier (Umesh et al., 2020). The authors propose that regular training enhances individuals' perception of effort leading to a greater awareness of effort costs. However, from a Learned Industriousness perspective, we would expect regular physical activity to increase both motor cortical thickness and the preference for effort. Thus, a positive rather than negative relation between motor cortical thickness and the valuation of physical effort would be expected.

Currently, there is limited research examining the neural aspects of (de)valuation of physical effort. Results about neural correlates of the value of physical effort are only partly embedded into the knowledge from the cognitive domain and the theoretical foundations.

Measurement approaches

We identified three methods used to measure the value of physical effort: (1) actual effort investment and performance, (2) (hypothetical) choice/preference, and (3) self-report measures. In several of the included studies, the exertion of physical effort was interpreted as a measure of how much a person likes and seeks out effort (Bustamante et al., 2014; Rodman et al., 2021; Stanek & Richter, 2021; Toro-Serey et al., 2022). Besides the amount of force (i.e., physical effort) (Stanek & Richter, 2021), also the persistence of effort investment (Bustamante et al., 2014) was used as a proxy for effort preference. Exerting greater force and persevering longer are interpreted as higher valuations of effort. For example, in one classical physical effort paradigm, participants must repeatedly squeeze a hand grip dynamometer with high or low force to gain a reward (Rodman et al., 2021; Stanek & Richter, 2021). When individuals apply more force than required, it is interpreted as a valuation of physical effort, as the extra effort is not used as an instrument to obtain something. Conversely, when individuals drop out of a trial and save energy, it suggests that the reward is not important enough to justify the required physical effort. Thus, physical effort is seen as an instrument rather than a reward.

Another common method to measure the preference for effort is to evaluate effort choices (e.g., Bernacer et al., 2019; Chong et al., 2018; Sullivan-Toole et al., 2019; Umesh et al., 2020). In a classical effort-discounting task, participants repeatedly choose between (A) an effortless option with a fixed reward and (B) a higher reward option discounted by effort. The reward and effort levels differ between trials. Analyzing individuals' choice patterns indicates how much the exerted effort devalued the reward. The more effort individuals are willing to apply to gain a smaller reward, the greater the value of effort.

Self-report measures explicitly targeting the intrinsic value of effort have found little use so far. Existing scales mainly assess factors like willingness to exert (Jonker et al., 2010; Toering et al., 2009; Van Yperen et al., 2021) or enjoyment of exerting physical effort (Wright et al., 2005) rather than directly measuring the value of effort itself. Nonetheless, one can derive implications about the valuation of effort: The greater the preference for challenging tasks, the willingness to exert effort, and the greater the enjoyment during physical effort exertion, the more effort itself is rewarding for an individual.

Effort function: physical effort adds value to its outcome

Ten studies investigated physical effort adding value to its outcome (Table 2). These articles share the assumption that outcomes that require effort (e.g., products/items, decisions) are more valued than the same outcomes if they require less effort.

Evidence that physical effort enhances the value of its outcome

Exerting effort enhances the value of the outcome of effort (Alessandri et al., 2008a; Klein et al., 2005; Vinckier et al., 2019). When participants exerted physical effort to obtain two different positive stimuli, they preferred the stimulus that required more effort over the one that required less effort (Klein et al., 2005). Building on this, in a further study, participants engaged in a grip force task, applying varying amounts of force (high or low effort) for either shorter (1 s) or longer (5 s) durations (Alessandri et al., 2008a). Although participants generally preferred low-effort, short-duration tasks, they exhibited a distinct preference for the stimulus associated with higher effort when compared directly with low-effort stimuli (Alessandri et al., 2008a). Similarly, individuals retrospectively are more confident about their decisions' correctness when they apply more physical effort (i.e., grip force) to indicate it (Turner et al., 2021). Additionally, the history of decision-making and success are considered when it comes to the valuation of an outcome (Vinckier et al., 2019). When people decide to pursue something and exert physical effort to obtain it, the item is liked more than items that were not pursued. Crucially, the exerted physical effort enhances its outcomes' value. Moreover, pursued and obtained items are liked even more (Vinckier et al., 2019).

Developmental aspects

Interestingly, this phenomenon has been observed in children as young as five years old (Alessandri et al., 2008b; Kiefer et al., 2023). Even at this young age children prefer outcomes that required more effort (Alessandri et al., 2008b) and products that they have created with their own physical or cognitive effort over products from others (Kiefer et al., 2023). Notably, the older the children, the more they are willing to pay for their own products (Kiefer et al., 2023). A similar study demonstrated that children who exerted greater effort to obtain a reward valued the reward more highly than those who exerted less effort (Lewis, 1964). However, this effect was significant for first-graders, whereas sixth-graders did not differ in their preference (Lewis, 1964). These findings imply that exerting effort increases the preference for an outcome even at a young age. Nevertheless, the dynamic of how this relationship develops with age is unclear.

Neural correlates

Three studies examined the neural response to the reward of effort (i.e., the outcome). In one study, participants chose between two options, in each trial, and were required to exert either high or low physical effort to receive a reward (Palidis & Gribble, 2020). Subsequently, participants received feedback on their accuracy and success. Interestingly, not the feedback on accuracy but on the reward elicited a significant neural response. High effort led to increased brain response to the outcome in the mid-frontal cortex or nearby areas, reflecting the spatial imprecision inherent to EEG measurements (Palidis & Gribble, 2020). This finding suggests that effort modulated the evaluation of reinforcement outcomes, rather than being processed purely as a cost or loss (Palidis & Gribble, 2020). Thus, invested effort retrospectively modulates reward processing. Further evidence comes from studies, focusing on the timing of effort valuation (Wu & Zheng, 2023) and the differences in neural activation for feedback on cognitive and physical effort (Jiang & Zheng, 2023). Wu and Zheng (2023) found that in an early phase of reward valuation (220–320 ms) an effort discounting effect was found in frontocentral areas, whereas in a later phase (600–1000 ms) an effort enhancement effect was displayed in centroparietal areas. This finding might offer insights into the apparent effort paradox (Inzlicht et al., 2018), as firstly effort has a discounting and later an enhancing effect (Wu & Zheng, 2023). Furthermore, results indicate that the greater the exerted effort, the greater the discounting but also the enhancement effect (Wu & Zheng, 2023). A further study investigated whether these reactions to effort feedback are similar in cognitive and physical effort (Jiang & Zheng, 2023). Exerting effort reduced early frontocentral reactions (220–230 ms) on feedback in a domain-general manner. However, the later activation (320–420 ms) in the parietal areas was domain-specific, as a higher activation for feedback on physical effort exertion was found. The feedback valence (i.e., positive or negative) enhanced the brain activation, speaking in favor of effort adding value (Jiang & Zheng, 2023).

In summary, there is already strong evidence for physical effort to enhance the outcome value (Alessandri et al., 2008a; Turner et al., 2021; Vinckier et al., 2019). Additionally, first neural insights help to understand the timing and process of enhancing reinforcement motivation (Jiang & Zheng, 2023; Palidis & Gribble, 2020; Wu & Zheng, 2023). However, although the current studies investigate physical effort, they do not use sports and exercise paradigms.

Measurement approaches

We identified three methods of measuring the value of effort's outcome: (1) choice/preference for the outcome, (2) confidence in the correctness of a decision, and (3) the measurement of neural correlates. In the first method, participants repeatedly decide between two objects. Both are equivalent, except that one is paired with high and the other with low effort. The choice pattern reflects the valuation of the outcome based on effort investment (e.g., Alessandri et al., 2008b). Choosing the high-effort option more frequently indicates a higher value placed on effort and vice versa. Another study directly asked participants to rate their preference for an item, which yielded a similar interpretation. Higher preference indicates higher outcome valuation through effort investment (Vinckier et al., 2019).

The second approach uses choice confidence as a proxy for the valuation of effort's outcome (Turner et al., 2021). Participants repeatedly performed a task and reported their answers by exerting physical effort. The required amount of physical effort varied between trials. Later, participants rated their confidence regarding the correctness of their answers. Since decisions were indicated by exerting effort, they reflect the outcome of effort. Thus, decision confidence provides information about the value of effort's outcome: higher confidence indicates a higher value placed on the outcome of their effort.

Thirdly, activation in brain areas associated with effort discounting or enhancement was used as a measure for the evaluation of effort (Jiang & Zheng, 2023; Wu & Zheng, 2023). The higher the activation in areas associated with the enhancement of effort (parietal areas) and the lower the activation in areas associated with the discounting effect (frontocentral areas) the greater the apparent value of effort.

Discussion

In sport psychology, our understanding of the functions of physical effort beyond its function as an instrument is limited. To address this gap, we conducted a literature review on physical effort *as a reward* and *as adding value* to an outcome in sports and physical activity. After our comprehensive literature search identified about 28,000 candidate papers from various disciplines, a machine-learning-supported review of the literature (*ASReview*) yielded 14 relevant articles (plus one theoretical article). We updated the literature search in November 2023, where about 4800 candidate papers were found. Screening the abstracts in ASReview resulted in four further relevant articles. In the peer-review process, another four articles were identified as relevant. Resulting in a total of 23 articles included in this review. All in all, three articles directly investigated *effort as a reward*, whereas another nine articles provided indirect insights. Additionally, ten articles investigated *effort as value added* to outcomes. Finally, although all relevant articles investigated physical effort, only six of them approached it in sports and exercise.

These numbers highlight the scarcity of research on the value of physical effort in sports and exercise. Nevertheless, the reviewed literature provides preliminary insights into the processes and conditions under which effort can generate value. Most importantly, the available evidence supports the idea that physical effort can have inherent value (e.g., Bernacer et al., 2019; Rodman et al., 2021; Sullivan-Toole et al., 2019), and can add value to an outcome (e.g., Jiang & Zheng, 2023; Palidis & Gribble, 2020; Turner et al., 2021; Vinckier et al., 2019; Wu & Zheng, 2023). It is worth noting that different measurement approaches have been employed, potentially limiting comparability between studies.

In our review, we excluded studies involving animal research. However, it is important to note that a substantial body of literature with animal subjects exists that examines the value-generating functions of physical effort more thoroughly and explicitly than most human studies. For example, animal research has provided direct insights into the valuation of physical effort and its outcome based on theories such as effort justification (Jellison, 2003; Kacelnik & Marsh, 2002) and Learned Industriousness (Laurence et al., 2015). These findings highlight the necessity of incorporating insights from animal research to deepen our understanding of physical effort valuation in human contexts. Consequently, we integrated relevant findings from animal studies into our discussion to enhance the overall implications of our review.

Physical effort can be valuable

Regularly exerting physical effort can increase its inherent value (Bernacer et al., 2019). This increased valuation is reflected in changes in effort preference and behavior, as well as in neural activation. Particularly the activation of the anterior cingulate cortex, which plays a crucial role in integrating the value and costs of effort (Chong et al., 2017), and its functional connectivity with the Amygdala was altered. This indicates an improved capability of exerting greater effort for greater rewards (Floresco & Ghods-Sharifi, 2007) (for a meta-analysis on the neural correlates of physical effort and its value, see Lopez-Gamundi et al., 2021). Crucially, these results suggest L*earned Industriousness* (Eisenberger, 1992) as a fundamental mechanism behind effort valuation across human and non-human animals.

Once industriousness is learned, it produces a relatively stable behavioral pattern, which is also maintained in unpleasant situations, as observed in rats (Hart et al., 2017). This finding shares similarities with habit research, as both exhibit behavioral stability detached from a concrete value or goal (Adams & Dickinson, 1981; De Wit et al., 2009; James, 1890). Thus, it appears challenging to discern the learning mechanism behind a behavior: Regularly choosing and exerting physical effort can lead to (1) an increase of efforts' inherent value (Learned Industriousness), (2) the formation of a habit of exerting high levels of effort, or (3) involves both processes simultaneously. Further research is needed to unravel the nature of this learning mechanism and whether behavioral stability also holds among humans.

Further insights into the process of effort becoming rewarding, come from studies rewarding cognitive effort exertion instead of performance. This approach motivates people to exert effort even without a tangible reward (Lin et al., 2024). However, this willingness to exert effort does not generalize to transfer tasks (Lin et al., 2024). Comparable studies conducted in schools found feedback on effort rather than on performance, leading to a greater preference for challenging tasks (e.g., Mueller & Dweck, 1998). Such findings help apply Learned Industriousness to everyday life and advise parents, teachers, and coaches to promote the value of effort better (Eisenberger, 1992; Mueller & Dweck, 1998).

Similar studies should be conducted for physical effort in the context of sports. For instance, a sample of initially inactive individuals could be rewarded for either exerting physical effort or for demonstrating good performance during a lengthy training period. Before and after this, the inherent value of physical effort could be assessed. If people can learn to value the exertion of effort, we would anticipate an increase in participants' willingness to exert physical effort after the training phase in the effort group, but not in the performance group. Furthermore, it would be an intriguing question whether participants' affective responses to effort exertion would change during such a training period, particularly in terms of how these changes might influence their motivation and adherence to physical activity. Understanding how these affective responses evolve could provide valuable insights into the psychological mechanisms that underpin sustained engagement in physical activity and inform strategies for enhancing motivation among individuals who are initially inactive.

Exercisers and non-exercisers show different automatic affective responses towards physical activity stimuli (Cheval et al., 2018). The underlying reason for this difference remains unclear, yet. However, a recent meta-analysis found that cognitive effort is robustly associated with negative affect across various tasks, populations, and countries (David et al., 2024). The authors suggest that highly industrious individuals (i.e., those with a high 'Need for Cognition' (Cacioppo & Petty, 1982) tend to choose effortful tasks despite the high effort involved, rather than because of it (David et al., 2024). Whether the affective response in the sports context can be modulated through regular training, potentially via the associated release of endocannabinoids during physical exertion (Dietrich & McDaniel, 2004), remains an open empirical question.

Generalization of effort

While rats show a generalization of valuing effort across physical and cognitive tasks (e.g., decision-making, persistence, and problem-solving; Laurence et al., 2015), the picture is less clear when it comes to humans: An experimental study found no support for value generalization from physical to cognitive effort (Bustamante et al., 2014). As animal research suggests, this might be due to different neural bases of physical and cognitive effort (Hosking et al., 2015). However, correlational studies comparing athletes and non-athletes found evidence for the tendency to generalize effort preferences across effort domains (Chong et al., 2018; Jonker et al., 2010; Toering et al., 2009), indicating a moderate relationship between the willingness to exert physical and cognitive effort (Schmidt et al., 2012). However, recent findings suggest that individuals differentiate specifically in their valuation of physical versus cognitive effort (Wolff et al., 2024). To further investigate the generalization of effort's value between domains, future studies can use a validated parallel measurement approach for both physical and cognitive effort (Lopez-Gamundi & Wardle, 2018).

Furthermore, it remains unclear whether the valuation of physical effort is task-specific. For instance, individuals who inherently value exerting effort in strength training may not necessarily find similar value in endurance training. According to the theory of Learned Industriousness, the valuation of effort is likely to generalize across different tasks (Eisenberger, 1992), yet we found no studies that specifically investigated this phenomenon within the context of sports and physical activity.

Developmental aspects

Effort is not always deployed in a primarily cost-conscious instrumental manner (e.g., Stanek & Richter, 2021). This seems especially true during adolescence and points to a sensitive developmental phase for the learning of valuing effort (Rodman et al., 2021; Sullivan-Toole et al., 2019). Compared to adults who predominantly exert effort strategically as an instrument to maximize rewards and minimize effort (Rodman et al., 2021), adolescents seem less sensitive to effort costs, thus, exerting more effort than a task requires (Sullivan-Toole et al., 2019). These differences might be influenced by changes in striving for autonomy (e.g., Steinberg & Morris, 2001) and in the neural (e.g., Wittmann et al., 2023) or hormonal system (e.g., Buchanan et al., 1992; Cyranowski et al., 2000) during adolescence, and on the other hand, rising opportunity costs of effort with aging (Cardini & Freund, 2021). Given this critical developmental phase, it may be beneficial for physical education teachers to reward exerted effort, rather than solely focusing on performance. By doing so, they might enhance the inherent valuation of physical effort, helping to promote sustained engagement in sport and exercise over the long term.

Physical effort adds value to an outcome

Exerting physical effort increases the value of an outcome in both humans and animals (Alessandri et al., 2008a, 2008b; Palidis & Gribble, 2020; Turner et al., 2021; but see also Jellison, 2003); this effect is amplified when physical effort is paired with success (Vinckier et al., 2019). Moreover, exerting physical effort increases retrospective confidence in one's choice (Turner et al., 2021), suggesting that choices that require effort are valued more. Neuro-scientific research found higher activation in the mid-frontal cortex after receiving a reward for exerting high (vs. low) effort, indicating a greater valuation of high- vs. low-effort rewards (Palidis & Gribble, 2020). Furthermore, it was found that effort first has a discounting effect, visible through activation in frontocentral areas, whereas later it has an enhancing effect (Wu & Zheng, 2023). These effects are interrelated, as the greater the discounting effect, the greater the enhancing effect (Wu & Zheng, 2023), speaking in favor of effort-adding-value.

While this idea aligns with everyday experiences (e.g., being proud of having a toned body due to regular exercise; a finisher T-shirt from a marathon vs. buying the same T-shirt; winning a race against a fast vs. slow opponent), there is a notable lack of studies investigating it specifically within sports and physical activity contexts. Understanding why some individuals invest substantial physical effort to achieve specific outcomes could provide valuable insights into how we can better support goal attainment. The IKEA effect, where self-assembly increases perceived value (Norton et al., 2012), for example, could be applied to sports by examining how effort enhances the perceived value of a marathon finisher's shirt. An experiment could compare one group receiving the shirt at registration with another receiving it only after completing the marathon. Measuring the difference in perceived value could reveal how effort-based rewards boost motivation, informing strategies for more effective incentives in recreational sports. Athletes could also benefit from a deeper understanding of this mechanism: Notably, the increased value of an outcome due to effort investment often manifests only after the effort has been expended. In competitive contexts, particularly when facing a superior opponent, the training motivation might be reduced as there is little expectation of victory. However, if the perceived value of success could be instilled before the event, this may enhance both training and competition motivation, thereby increasing the likelihood of success. To effectively explore these underlying mechanisms, the development of standardized and valid methods for measuring the value of physical effort is essential.

Measuring physical effort's value

There is no consensus on how best to operationalize the value of effort. Typically, related factors, such as performance or self-reported preference, are used as proxies for effort valuation (see also Haynos et al., 2022). However, the interpretation of the observed behaviors and statements remains unclear: Does effort itself become a reward? Does the same behavior require less effort? Or does effort's product become more important as an extrinsic reward? To illustrate, the preference for effort provides valuable insights about effort's value; however, different theories might offer different explanations for the result. The theory of *Learned Industriousness* asserts that repeatedly choosing the high-effort option without a reward indicates that effort gained intrinsic value. On the other hand, habit research proposes that high-effort choices may reflect habitual behavior rather than changes in effort evaluation. Both theories make similar predictions about the measured behavior (i.e., effort

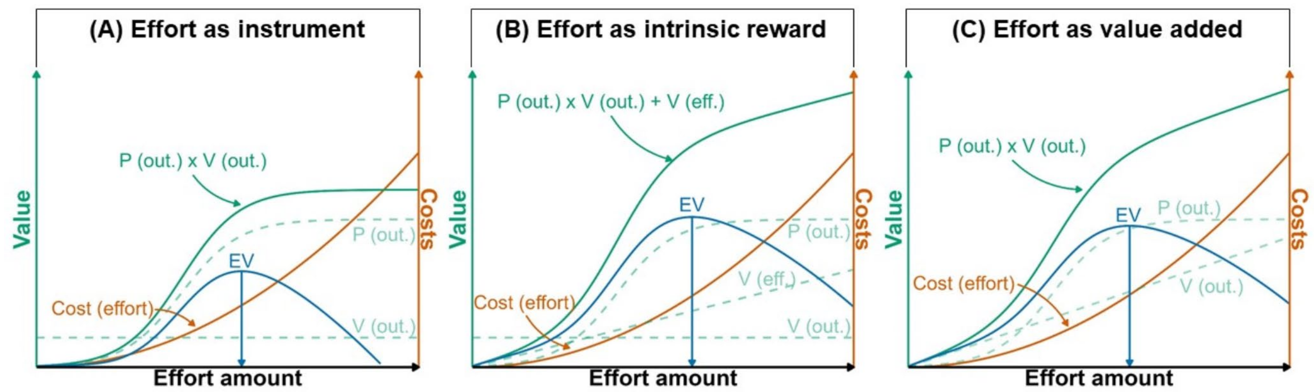

Fig. 2 Illustration of the expected value (EV; blue) and its components for each function of effort. *Note.* Figure adapted from Inzlicht et al. (2018). The individual curves must be retrieved empirically. Since the empirically correct curves are unknown, we used exemplary functions. **A:** The expected outcome of effort (solid green) is the product of the probability [P (out.)] and the value [V(out.)] of effort's outcome. The probability of earning an outcome rises with the amount of effort. However, the outcome's value remains constant. **B:** The expected outcome of effort (solid green) is extended by effort's intrinsic value [V (eff.)], in contrast to (**A**). Effort's intrinsic value rises the more effort is exerted. **C**: The expected outcome (solid green) is composed of its probability [P (out.)] and its value [V (out.)]. In contrast to (**A**), the outcome's value increases with the amount of exerted effort

choices), which makes it difficult to distinguish between inherent value and habit formation. To address this, we suggest using instruments directly tapping into effort's value to capture the underlying motivation and intention in addition to currently used behavioral methods (e.g., a Value of Physical Effort Scale, Bieleke et al., 2023; or a Physical Effort Scale, Cheval et al., 2023). In addition to the currently used measurements, it could be helpful to assess a great variety of correlates of effort valuation, such as brain activation in value-related areas (e.g., ventromedial prefrontal cortex, dorsal anterior cingulate cortex; see e.g., Arulpragasam et al., 2018; Lopez-Gamundi et al., 2021), neuroactive substance release (e.g., endocannabinoids, Dietrich & McDaniel, 2004; dopamine, Hosking et al., 2015; Lee et al., 2020), affective response (Affective Exercise Experiences questionnaire, AFFEXX, Ekkekakis et al., 2021; NASA Task Load Index, S. G. Hart & Staveland, 1988; Positive and Negative Affect Scale, PANAS, Watson et al., 1988), and preference for effort intensities (Preference for and tolerance of the intensity of exercise questionnaire, PRETIE-Q; Teixeira et al., 2023). Examining these correlates could provide deeper insight into the differences and similarities across effort's different functions and how these functions might be enhanced. Additionally, we recommend analyzing the relationships between currently used measurement methods to increase confidence in findings and improve the comparability of the results across studies.

The use of theoretical frameworks to investigate the functions of physical effort

To better understand the different functions effort can have, theoretical frameworks that can incorporate all these functions offer a powerful starting point. One such theory is the *Expected Value of Control (EVC)* theory (Shenhav et al., 2013). EVC theory is a mechanistic and formally explicit conceptualization of effort application as a reward-based choice (Inzlicht et al., 2018). Importantly, EVC theory can account for the components of decisions individually for each effort function (Fig. 2). Independent of the effort function, effort costs (orange) and the expected outcome (solid green) increase with the amount of effort expended. However, the value curve of effort's expected outcome (solid green) comprises different shapes depending on the effort function, as it is composed of subcomponents differing between functions (dashed green). The expected value (blue), which determines the actual effort exertion, differs between the effort functions, as it displays the expected outcome relativized by the costs.

These kinds of theories could be used as theoretical underpinning and to derive testable empirical predictions with respect to effort's different functions. By breaking down the expected value into its components, the EVC theory can guide the design of studies to manipulate these factors. For example, one can determine the empirical cost and value curves for different domains (e.g., cognitive vs. physical effort) or different groups of people (e.g., athletes vs. mathematicians) or purposefully vary or hold constant components of the theory. A theory-guided approach will contribute to a better understanding of how effort functions in various contexts.

Future directions and practical implications

Currently, there is limited direct evidence of how physical effort becomes inherently rewarding and adds value to an outcome, especially in the sports and exercise context. Understanding why different populations (e.g., athletes, inactive individuals, people of various ages) exert effort could provide valuable insights for creating targeted interventions that support goal attainment. For instance, inactive individuals are often made aware of the health benefits of an active lifestyle (Fredriksson et al., 2018), yet many remain inactive (Gupta et al., 2023). If individuals could learn to inherently value physical effort, it may increase their motivation to engage in exercise (Bieleke et al., 2023).

For athletes, it is important to promote an appreciation not only for achieving specific outcome goals (e.g., winning a gold medal at the Olympics) or performance goals (e.g., outperforming teammates in a 10K race) (Dweck, 2014; Nicholls, 1984). In these cases, effort is perceived merely as an instrument, but promoting the inherent value of physical effort itself may enhance their overall enjoyment and training motivation. This suggests that the shift in focus—from viewing effort only as a costly instrument to additionally recognizing its inherent value—could potentially influence other motivational components, such as a transition from performance goals to mastery goals, which are beneficial for athletic performance (Duda & Ntoumanis, 2003). On the other hand, visualizing the value and joy associated with achieving a goal (e.g., winning a goal medal) could further boost their commitment during training (i.e., focusing on effort as value added).

These examples highlight the potential benefit of further investigating the different functions of physical effort across specific contexts. Developing a more nuanced understanding of why individuals choose to exert effort—or refrain from doing so—offers several opportunities for enhancing motivational strategies for physical exertion.

Limitations

Despite the strengths of this review, including a thorough and systematic literature search supported by a machine-learning tool, as well as the synthesis of the relevant findings and the identification of knowledge gaps for further research, certain limitations warrant careful consideration. First, we employed ASReview, a machine-learning tool that enhances transparency and reduces human bias in title and abstract screening (van de Schoot et al., 2021). While ASReview enabled the efficient screening of large volumes of records—an approach that mitigates the risks of fatigue and manual biases—it involves a trade-off due to its partially customizable algorithm, resulting in reduced control over certain outcomes. Nonetheless, this tool has demonstrated its value in large-scale reviews and supports a robust approach to managing extensive datasets (e.g., Ekelund et al., 2023; Feil et al., 2023; Warren & Moustafa, 2023).

Additionally, general challenges related to database selection, search interface variability, and inclusion criteria are inherent to literature reviews (van der Akker et al., 2020) and cannot be fully addressed through machine-learning tools alone. In our case, for example, the search was conducted in English and limited to four databases, which may have led to some studies in other languages or additional databases being excluded. Future research could expand these parameters to capture an even broader range of relevant studies.

Moreover, the diversity of study designs included in this review further highlights the wide relevance of this topic but calls for caution in drawing causal conclusions (the "apples and oranges" issue; e.g., Higgins, 2024). To address this, we have categorized results under broader topics and provided a dedicated section that highlights key differences in measurement approaches. This heterogeneity offers a unique perspective on the varied approaches to studying the value-generating functions of physical effort, suggesting a need for more standardized methods in future work to enhance comparability and interpretative clarity.

Lastly, due to a scarcity of studies specifically focused on sports contexts, we included research from other physical domains where participants did not engage in sports or exercise per se (e.g., finger-tapping or clicking tasks). While this inclusion highlights a significant gap in the literature, it also limits the direct applicability of our findings to real-world exercise scenarios, where additional hormonal and neural processes may significantly influence outcomes. Nevertheless, the insights gained here provide valuable implications for understanding motor performance and could serve as a foundation for targeted research in more specific sports and exercise contexts.

Conclusions

This scoping review synthesized existing literature on the ways in which physical effort can be valuable and/or add value in physical activity contexts. While contemporary theories acknowledge the importance of effort, frameworks explicitly integrating effort as inherently valuable (e.g., *as a reward* or *added value*) remain lacking. While some insights come from studies using non-sport physical tasks like finger tapping or mouse clicking, research specifically on the valuation of effort in actual sports and exercise contexts is scarce.

To advance our understanding of effort's functions in physical activity, future research would benefit from developing a coherent theoretical framework that accounts for the different functions of physical effort. Investigating how individual differences shape the valuation of effort, alongside longitudinal studies examining how this valuation evolves over time and affects motivation and engagement, would provide critical insights. By addressing these gaps, we can enhance our understanding of how physical effort contributes to well-being and goal attainment. This knowledge would not only enrich theoretical perspectives but also have practical applications in promoting sports, physical activity, and broader health interventions.

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Declarations

Conflict of interest The authors declare that they have no competing interests.

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