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Review

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Effects of Combining Occupationally Relevant Physical and Cognitive Tasks. A Systematic Review

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Abstract

Objectives: Physical and cognitive tasks occur together in many occupations. Previous reviews of combined tasks have mainly focused on their effects in a sports context. This review investigated to which extent combinations (concurrent or alternating) of occupationally relevant physical and cognitive tasks influence responses reflecting biomechanical exposure, stress, fatigue, performance, and well-being.

Methods: We searched Scopus, Pubmed, Cinahl, and Psychinfo for controlled experiments investigating the effects of combinations of occupationally relevant physical and cognitive tasks in participants aged 18 to 70. In total, we identified 12 447 records. We added recent papers that had cited these studies (n = 573) to arrive at a total of 13 020 publications. After screening for relevance, 61 studies remained, of which 57 were classified to be of medium or high quality. Of the 57 studies, 51 addressed concurrent tasks, 5 alternating tasks, and 1 both concurrent and alternating tasks.

Results: Most studies of concurrent physical and cognitive tasks reported negative effects, if numerically small, on indicators of biomechanical exposure, fatigue, and performance, compared to a physical task alone. Results were mixed for stress indicators, and well-being was too little studied to justify any conclusions. Effects depended on the tasks, including their intensity and complexity. Alternating physical and cognitive tasks did not appear to influence outcomes much, compared to having passive breaks in-between physical tasks.

Conclusions: The reviewed evidence indicated that concurrent physical and cognitive work tasks have negative, yet small effects on biomechanical indicators, fatigue and performance, compared to performing the physical task alone, but only if the physical task is intense, and the cognitive task is complex. Alternating between physical and cognitive tasks may have similar effects as breaking up physical tasks by passive breaks, but studies were few. Future studies should address ecologically valid combinations of physical and cognitive tasks, in particular in controlled field studies devoted to the long-term effects of combined work.

Keywords: cognitive work; fatigue; performance; physical work; stress

What's Important About This Paper?

This systematic review explores the extent to which combinations of physical and cognitive tasks influence important occupational outcomes. Adding a cognitive work task on top of a physical task has negative, yet small effects on load, fatigue, and performance, while effects on stress are mixed, and well-being is too little studied. Alternating between physical and cognitive tasks does not appear to influence outcomes much, compared to alternating with passive breaks, but studies are few. Thus, this review offers decision support when designing jobs comprising both physical and cognitive demands.

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Introduction

Both physical and mental work demands are important in determining the risk for occupational disorders (de Kok et al., 2019). 'Physical' demands occur in tasks requiring a muscular effort (Winkel and Mathiassen, 1994), while 'mental' demands may occur even in tasks that can be performed without any physical effort. Mental demands may be associated with the work task *per se* posing demands on cognitive processes (Ackerman and Kanfer, 2009), or they may occur as a result of psychosocial factors at work, such as leadership and social support (Bakker and Demerouti, 2007). Also, other stressors in the work environment, such as distractions, hostile customers, or extreme temperatures, may lead to mental demands (Johansson et al., 1996; Hjortskov et al., 2004; Webb et al., 2011; Bhattacharyya et al., 2017). Physical and mental demands occur together, to different extents, in many occupations (Mehta, 2016). For instance, in a Swedish survey from 2018, workers in healthcare, hotels, restaurants, and administrative jobs reported having both physically and mentally demanding work tasks (The Swedish Work Environment Authority, 2018). Physical demands vary between different worker groups; in general, blue-collar workers are more physically active at work than white-collar workers (Steele and Mummery, 2003; Proper and Hildebrandt, 2006). While it is possible to think of occupational tasks that are almost purely mental, physical-only tasks hardly exist; any physical task will also be associated with mental processes as an integrated part of the task requirements; possibly with the exception of highly automated tasks such as walking.

Previous occupational health research addresses, to a large extent, the effects of either physical or cognitive tasks, and does not consider combined exposures (Mehta, 2016). The present review specifically considers the effects of combining physical demands ('physical tasks') with cognitive demands ('cognitive tasks') in working life. While psychosocial factors and stressors in the work environment are important to both acute responses (Blangsted et al., 2004; Hjortskov et al., 2004; Schleifer et al., 2008) and workers' long-term health (Hoogendoorn et al., 2001; Bakker and Demerouti, 2007), the present review focuses on demands occurring as an integrated property of the *work task*, i.e. the requirements associated with performing the task.

Physical and cognitive work tasks may occur both concurrently and in an alternating pattern. *Concurrent* physical and cognitive demands have been suggested to occur, for example, in manufacturing (Mozrall and Drury, 1996; Thorvald et al., 2019) and healthcare (Freimann et al., 2013, 2016). *Alternations* between tasks of a predominantly physical or predominantly cognitive character may occur in other occupations, such as retail and some industrial jobs (Jahncke et al., 2017). Concurrent combinations of physical and cognitive tasks appear to influence motor performance and endurance time compared to only doing the physical task, either in a negative way because the effort increases (Au and Keir, 2007; Mehta and Agnew, 2011, 2012a; Srinivasan et al., 2016; Longo et al., 2018), or positively, by increasing endurance through distraction (Blanchfield et al., 2014; Aleksandrov and Knyazeva, 2017; Grande-Alonso et al., 2020; Cruz-Montezinos et al., 2021). Even the effects on stress and cardiovascular responses appear to be mixed (Finsen et al., 2001a; Alkjær et al., 2005). Alternating tasks, that is, performing a physical task for a while, followed by a cognitive task, have been suggested to improve cognitive performance (Tomporowski, 2003). A cognitive task performed between bouts of a physical task in an alternating pattern has been suggested to improve recovery from fatigue caused by the physical task (Asmussen and Mazin, 1978; Stock et al., 2011), and to lead to improved cognitive performance (Tomporowski, 2003), or at least no deterioration in performance over time (Mathiassen et al., 2014).

Combinations of physical and cognitive tasks may, thus, have effects on biomechanical exposures, stress, fatigue, performance, and well-being, even if different studies disagree about the direction of these effects. Previous reviews devoted to combinations of physical and cognitive tasks have addressed the effects of intense physical exercise on cognitive task performance (Etnier et al., 1997; Tomporowski, 2003; McMorris and Hale, 2012), while others have been devoted to the effects of mental fatigue on physical performance in a sports science context (Van Cutsem et al., 2017). The exposures addressed by these reviews are not compatible with occupational life. Other reviews of task combinations have other target populations than the usual working population, such as the elderly (Falck et al., 2019), or have focused on specific outcomes (Dihr et al., 2021) or measurement methods (Mehta and Parasuraman, 2013). Thus, no review has, to the best our knowledge, addressed combinations of physical and cognitive tasks in an *occupational* context. A better understanding of how physical and cognitive work tasks can be combined in a 'just right' pattern to improve performance, well-being and health would serve employers with a basis for re-designing work to become sustainable (Holtermann et al., 2019).

Therefore, this systematic review of controlled experimental studies aims to summarize the available evidence on the extent to which combinations of occupationally relevant physical and cognitive tasks (concurrent or alternating) influence responses reflecting biomechanical exposure, stress, fatigue, performance, and well-being in adults of working age, that is, 18 to 70 years of age.

Methods

In- and exclusion criteria

Type of study

We included original and peer-reviewed papers in English, describing controlled experiments. We excluded reviews, conference proceedings, position papers, and studies with a non-experimental design. We had no restrictions on the publication date. Further screening was organized according to the Population, Intervention, Comparison and Outcome (PICO)-model (Shamseer et al., 2015).

Population

We included studies on healthy adults between 18 and 70 years of age, that is, of working age. We did not have any criteria for ethnicity or race.

Intervention/exposure

We included studies addressing combinations of physical and cognitive tasks; either concurrent or alternating. We did not have restrictions as to whether the physical or the cognitive task was the primary focus.

In terms of the physical task, we included studies addressing tasks considered to have at least some occupational relevance, for example, lifting, assembling, computer-related tasks, and submaximal isometric or dynamic efforts at an intensity below 50% Maximal Voluntary Contraction (MVC). Studies of tasks occurring very rarely in occupational settings were excluded, such as running, biking, or exertion of maximal force. We also excluded studies of the effects of external exposures, such as perturbations (e.g. sideways mechanical pushes while performing cognitive tasks; Stenlund et al., 2015) and electric shocks (Thackray and Pearson, 1968), as well as studies of the effect of environmental factors, such as cold or hot weather conditions (Bhattacharyya et al., 2017).

In terms of the cognitive task, we included studies with an explicit, preferably standardized, cognitive task. We excluded studies where cognitive demands were not an integrated part of the work task, that is, were 'external' to the task, such as studies devoted to effects of time pressure (Birch et al., 2000), surveillance (Blangsted et al., 2004), and false feedback (Schleifer et al., 2008).

Control

We included studies comparing concurrent or alternating physical and cognitive tasks with control condition(s) consisting of only physical or only cognitive tasks, as well as studies comparing different combinations, that is, conditions with different cognitive loads and/or different temporal patterns of alternations. Thus, we excluded studies reporting outcomes for only one combination, without a comparison.

Outcome

We included studies reporting outcomes related to at least one biomechanical exposure, stress, fatigue, well-being, and (physical and/or cognitive) performance. Examples of biomechanical outcomes are muscle activity, kinematics, and motor variability. Stress indicators include heart rate variability (HRV), blood pressure (BP), the activity of stress hormones, and perceived stress. Examples of fatigue indicators include electromyography (EMG) changes, changes in force-generating capacity, endurance time, and perceived fatigue. Well-being includes mood, energy, and (dis) comfort. Performance indicators are quantifiable results in standardized physical and/or cognitive tasks.

Search strategy

In close collaboration with an information specialist at the University library, we identified Mesh-terms and free search terms in accordance with our in- and exclusion criteria. Based on pilot searches, Scopus was selected as the primary database, with Cinahl, Psychinfo, and Pubmed as complementary databases. The search string was modified according to the terminology used in each database. Supplementary data, Appendix A (available at *Annals of Occupational Hygiene* online) shows complete search strings for each database, which were then combined with the exclusion terms reported in Supplementary data, Appendix B (available at *Annals of Occupational Hygiene* online). A first search was performed in February 2016, and a complementary search for new studies in September 2019. We updated the search in September 2021 using the 'cited by' function in Google Scholar for all 51 papers remaining after the first two waves of screening (cf. Fig. 1).

Study selection

In the 2016 and 2019 searches, duplicate records were removed by the library information specialist. Then, one coauthor (C.L.) screened records for relevance, first based on titles and then on abstracts for records remaining at that point, using our inclusion and exclusion criteria. If inclusion/exclusion remained unclear after this screening, C.L. read and assessed the article in full text. In case of assumed relevance or uncertainty at this step, studies were included for further examination.

Two authors (S.M. and S.E.M.) then individually assessed the full text of papers passing this screening, and also the papers identified by the 'cited by' procedure

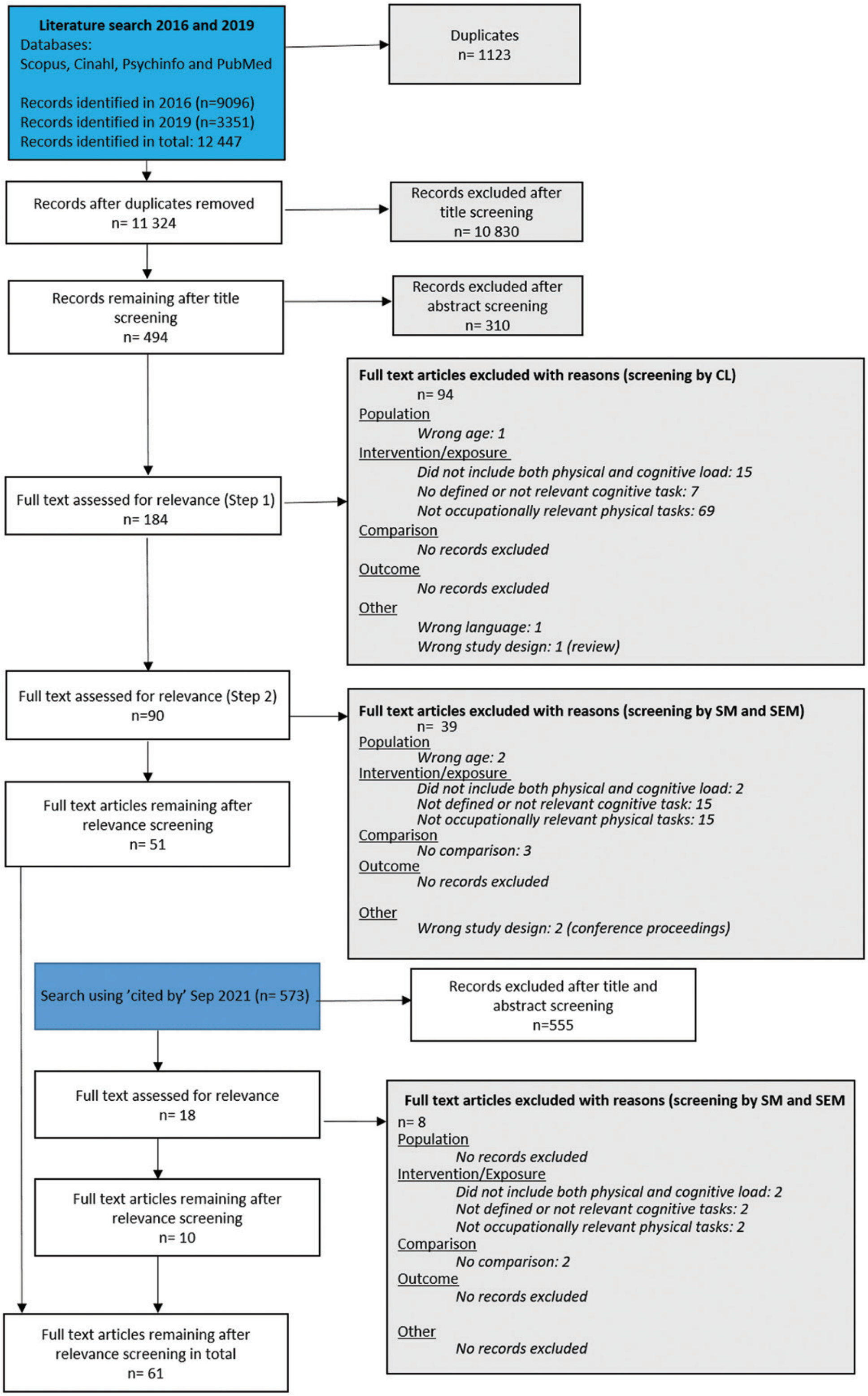

Figure 1. Flowchart of the literature search and screening process (modified from PRISMA).

in 2021, for relevance according to the in- and exclusion criteria. In case of disagreement, S.M. and S.E.M. discussed the verdict until reaching a consensus. The entire screening procedure resulted in a total of 61 papers proceeding to the assessment of quality (cf. Fig. 1).

Quality assessment and data extraction

Quality assessment

Two authors (S.H. and E.L.) independently assessed the quality of the 61 papers using (i) A standardized checklist modified from The Quality Assessment Tool for Quantitative Studies (National Collaborating Centre for Methods and Tools, 2010), and (ii) a checklist developed to fit the aim of the review. Both checklists can be found in Supplementary data, Appendix C (available at *Annals of Occupational Hygiene* online). The second checklist was developed partly because the standardized checklist included questions not considered to be relevant for controlled studies of physical and cognitive tasks (e.g. questions regarding blinding), and partly because the standardized checklist only resulted in a crude estimate of the quality of the included studies. This procedure could be used because the first checklist was considerably more generous than the second. Criteria for rating a study to be of low, medium, or high quality are described in detail in Supplementary data, Appendix C1 and C2 (available at *Annals of Occupational Hygiene* online). Disagreements in the quality assessment were discussed by S.H. and E.L. until reaching a consensus.

Studies of medium or high quality (57 studies, out of the 61 studies passing the relevance screening) were included in the eventual evidence synthesis. Examples of issues that led to low quality were a small study population with a between-groups design and rudimentary statistical analysis (Singh et al., 2002), and a non-randomized or non-counterbalanced study design (Pilcher and Baker, 2016).

Data extraction

For each study, S.H. and E.L. extracted and summarized data regarding relevant study design issues and results as per the focused outcomes.

Synthesis of results

In connection with the synthesis, studies were classified into showing either small, medium or large effects. If studies reported effect sizes, classification was based on established benchmarks for either Cohens *d´* (Cohen, 1988: small effect: ≥0.2 but <0.5; medium: ≥0.5 but <0.8; large: ≥0.8), or eta squared or partial eta squared (Lakens, 2013: small effect ≥0.01 but <0.06; medium: ≥0.06 but <0.14; large ≥0.14). If studies did not report effect sizes, the study was judged as showing a small effect if the change in percent from baseline to combined load was less than 10% for a particular outcome, or if only one outcome variable in one outcome category changed significantly (e.g. a significant change in heart rate but not in BP, HRV, and ratings of stress).

Results

Literature search and identification of articles

Figure 1 illustrates the article selection process, following a modified PRISMA format (Shamseer et al., 2015). The search in Scopus, Cinahl, PsychInfo, and Pubmed in February 2016 identified 9096 records, and the additional search in 2019 resulted in 3351 records, that is, a total of 12 447 records. Of the 184 papers remaining after screening on title and abstract, C.L. excluded another 94 papers based on full texts (cf. Fig. 1, showing reasons for exclusion). The 90 remaining papers were screened for relevance even by S.M. and S.E.M., excluding an additional 39 papers. The 51 papers left were assessed for quality by S.H. and E.L. The 2021 update resulted in 10 additional papers, after screening of relevance by S.M. and S.E.M., which were also quality assessed by S.H. and E.L. In Supplementary data, Appendix D (available at *Annals of Occupational Hygiene* online), we present tables providing an overview of the sample, exposure, protocol, outcome, and main results of these, in total, 61 articles.

Study characteristics

Of the 61 articles remaining after the final screening for relevance (cf. Fig. 1), 57 were regarded to be of high or medium quality (cf. Supplementary data, Appendix D, available at *Annals of Occupational Hygiene* online). The synthesis below concerns these 57 articles.

Population

A majority of the studies included both male and female participants (36/57). Thirteen studies included only female participants, 7 only males, and 1 study did not state the participants' sex. Sample sizes ranged from 9 to 137, with studies including 10 to 20 participants being most common (35/57). Mean age in the study population ranged between 20 and 44 years. In a majority of the studies, the mean age was between 20 and 30 years.

In many studies (24/57), the strategy for recruiting and selecting participants was not explicitly stated. In 14 studies, participants were university students and 15 studies reported that participants were recruited from the University community, with no further detail. Only six studies recruited participants from worker populations (Ekberg et al., 1995; Larsson et al., 1995; Birch et al., 2000; Ohlinger et al., 2011; Nino et al., 2020; Schellewald et al., 2021).

Intervention/exposure

Most of the 57 studies were devoted to concurrent physical and cognitive tasks (51 out of 57). Five addressed alternating physical and cognitive tasks (Asmussen and Mazin, 1978; Mathiassen et al., 2014; Mixter et al., 2019, 2020, 2021), and one included conditions with both alternating and concurrent tasks (Davis et al., 2002). In the screening process, we realized that the physical tasks could be categorized into three main categories, that is, (i) Isometric contractions, for example, hand grip or elbow flexion at a constant force in a fixed posture, (ii) Low-intensity dynamic contractions, for example, computer tasks, assembly tasks, or pipetting, and (iii) high-intensity dynamic contractions, for example, lifting. Similarly, we found that the cognitive tasks could be organized into three main categories: (i) tests of executive functions, for example, tests that challenge cognitive abilities such as inhibition and updating (e.g. Stroop-Color Word, N-back, or Task Switching), (ii) tests of memory recall, for example, remembering and recalling lists of words, numbers, or symbols, and (iii)

Table 1. Studies (n = 51) of *concurrent* physical and cognitive load classified into physical and cognitive task categories. Only studies of medium or high quality are shown. Outcome variables are stated after each reference (B = biomechanical; S = stress; F = fatigue; P = performance; W = well-being).

	Isometric contractions	Low-intensity dynamic contractions	High-intensity dynamic contractions
Executive functions	Au and Keir (2007) (B) Chatain et al. (2019) (B,S,F,P,W) Deeney and O'Sullivan (2017) (B,F) Evstigneeva et al. (2012) (F,P) Larsson et al. (1995) (B,S) Lundberg et al. (1994) (B,S) Mehta and Agnew (2011) (B) Voelcker-Rehage et al. (2006) (B,S,F)	Alkjær et al. (2005) (B,S,P) Biondi et al. (2021) (B,P) Birch et al. (2000) (B,P) Ekberg et al. (1995) (B,S) Frodsham et al. (2020) (51) Garde et al. (2002) (S,P) Guillery et al. (2013) (B) Huang et al. (2019) (P) Laursen et al. (2002) (B,P) Marshall et al. (2021) (B,P) Nino et al. (2020) (B) Ohlinger et al. (2011) (P) Qiu and Helbig (2012) (B,W) Schellewald et al. (2021) (P) Srinivasan et al. (2015) (B,P) Srinivasan et al. (2016) (B,S,F)	No study
Memory recall	Tomporowski et al. (2017) (P)	Bloemsaat et al. (2005) (B,P) Finsen et al. (2001a) (B) Finsen et al. (2001a) (B,S,F) Frodsham et al. (2020) (P) Grindle et al. (2018) (B) Larson et al. (2015) (P) Leyman et al. (2004) (B,P) Schellewald et al. (2021) (P) Shaikh et al. (2012) (B,S,F,P)	No study
Combined/complex processing	Cruz-Montecinos et al. (2018) (B,F,P) Guzmán-González et al. (2020) (B,S) Lundberg et al. (1994) (B,S) Mehta and Agnew (2012a) (F) Mehta and Agnew (2012b) (S,F,P) Mehta et al. (2012) (B,S,P) Mehta and Agnew (2015) (B,F) Mehta and Parasuraman (2014) (B,F,P) Vanden Noven et al. (2014) (B,S,F,P) Wasmund et al. (2002) (S) Yoon et al. (2009) (B,S,F)	Ekberg et al. (1995) (B,S) Frodsham et al. (2020) (P) Grindle et al. (2018) (B) Hernández Arellano et al. (2018) (B,S,P) Hughes et al. (2007) (B,S,P) Kolish and Schaefer (1996) (S,P,W) Larson et al. (2015) (P) Leyman et al. (2004) (B,P) Longo et al. (2018) (B) Qiu and Helbig (2012) (B,W) Schellewald et al. (2021) (P) Taelman et al. (2011) (S) Wang et al. (2011) (B,S,F)	Katsuhira et al. (2013) (B) DiDomenico and Nussbaum (2008) (B,P) DiDomenico and Nussbaum (2011) (B,S,P)

Table 2. Studies (*n* = 6) of *alternating* physical and cognitive load, classified into physical and cognitive task categories. Only studies of medium or high quality are shown. Outcome variables are stated after each reference (B = biomechanical; S = stress; F = fatigue; P = performance; W = well-being).

	Isometric contractions	Low-intensity dynamic contractions	High-intensity dynamic contractions
Executive functions	No study	Mathiassen et al. (2014) (S,F,P) Mixter et al. (2019) (F,P) Mixter et al. (2020) (S) Mixter et al. (2021) (S,F,P)	Davis et al. (2002) (B)
Memory recall	No study	No study	No study
Combined/complex processing	Asmussen and Mazin (1978) (F,P)	No study	Asmussen and Mazin (1978) (F,P)

tests of combined/complex processing, for instance, arithmetic tasks or problem-solving. Tables 1 and 2 present a summary of the categorized physical and cognitive tasks in the 57 studies. Further details of the studies can be found in tables D1 through D6 in the Supplementary data, Appendix (available at *Annals of Occupational Hygiene* online). Note that some of the studies included more than one combination of physical and cognitive task categories.

Synthesis of results

Studies with concurrent physical and cognitive tasks

Fifty-one studies investigated concurrent physical and cognitive tasks (Table 1).

Isometric contractions

Eighteen of the 51 studies of concurrent tasks used highly standardized upper-extremity isometric contractions of varying intensity as the physical task (Table 1).

Executive functions

Eight of the 18 isometric studies used tests of executive functions as the cognitive task. The most common cognitive task was different versions of the Stroop Color Word test (11 studies), in combination with upper extremity isometric tasks at different intensities; that is, either without external load (Lundberg et al., 1994), with a 1 kg load in each hand at different angles (Larsson et al., 1995) or by gripping a handle at 5, 35, or 45% MVC (Mehta and Agnew, 2011). For more information about task combinations and outcomes, see Supplementary data, Appendix D (available at *Annals of Occupational Hygiene* online).

Seven studies assessed biomechanical indicators. Two studies found no or small effects of concurrent load compared to a physical task only (Voelcker-Rehage et al., 2006; Au and Keir, 2007). In five of the studies, biomechanical indicators were affected negatively, with medium to large effect sizes (Lundberg et al., 1994; Larsson et al., 1995; Mehta and Agnew, 2011; Deeney and O'Sullivan, 2017; Chatain et al., 2019). One study suggested that force fluctuations and muscle activity were affected differently depending on the intensity of the isometric contraction, and that a concurrent load may lead to a redistribution of activity within and between muscles (Mehta and Agnew, 2011).

Three studies measured stress-related indicators (Lundberg et al., 1994; Larsson et al., 1995; Chatain et al., 2019). In one study, the effect was negative, yet small (Larsson et al., 1995). In a second study, stress indicators were affected negatively by a concurrent load, with medium to large changes from a condition with only a physical task (Lundberg et al., 1994). In the last study, the results were mixed (Chatain et al., 2019).

Three studies assessed fatigue-related indicators (Evstigneeva et al., 2012; Deeney and O'Sullivan, 2017; Chatain et al., 2019). One study reported a small effect of concurrent load (Evstigneeva et al., 2012), while the other two studies reported a negative effect (Deeney and O'Sullivan, 2017; Chatain et al., 2019), with quite large changes in endurance time and a large effect size.

Performance indicators were assessed in three studies (Voelcker-Rehage et al., 2006; Evstigneeva et al., 2012; Chatain et al., 2019). Two studies found no or small effects of concurrent load (Voelcker-Rehage et al., 2006; Evstigneeva et al., 2012). In the third study, cognitive performance decreased during concurrent loads with increasing cognitive difficulty, and effect sizes were large (Chatain et al., 2019).

One study assessed well-being as an outcome (Chatain et al., 2019) and found no effect of concurrent load.

Memory recall

Only one study addressed isometric tasks in combination with both immediate and delayed recall (Tomporowski et al., 2017). Performance was negatively affected in the concurrent condition, but only during a 50% MVC handgrip (Tomporowski et al., 2017). The effect size was large.

Combined/complex processing

Ten of the 18 isometric studies, all of which were of upper extremity loads, addressed combined/complex processing as the cognitive task (Table 1). The most common cognitive task was arithmetic processing (Wasmund et al., 2002; Yoon et al., 2009; Mehta and Agnew, 2012a, 2012b, 2015; Mehta and Parasuraman, 2014; Vanden Noven et al., 2014; Cruz-Montecinos et al., 2018; Guzmán-González et al., 2020).

Biomechanical indicators were assessed in six studies (Yoon et al., 2009; Mehta and Parasuraman, 2014; Vanden Noven et al., 2014; Mehta and Agnew, 2015; Cruz-Montecinos et al., 2018; Guzmán-González et al., 2020). Four of these found small or no effects of a concurrent load (Mehta andParasuraman, 2014; Vanden Noven et al., 2014; Mehta and Agnew, 2015; Cruz-Montecinos et al., 2018). In the remaining two studies, biomechanical indicators were negatively affected by a concurrent load, and effects were large (Yoon et al., 2009; Guzmán-González et al., 2020).

Stress indicators were assessed in three studies (Wasmund et al., 2002; Yoon et al., 2009; Mehta et al., 2012); one reporting no effect of concurrent load (Wasmund et al., 2002) and two reporting negative effects (Yoon et al., 2009; Mehta et al., 2012). In one study, HRV was only affected by a concurrent cognitive task during low-intensity (5% MVC) wrist and torso exertion (Mehta et al., 2012). On the other, cortisol levels and self-reported arousal were elevated during concurrent load, but the authors suggested that this could be due to anticipatory effects (Yoon et al., 2009).

Fatigue indicators were assessed in six studies (Yoon et al., 2009; Mehta and Agnew, 2012a, 2012b; Mehta and Parasuraman, 2014; Vanden Noven et al., 2014; Cruz-Montecinos et al., 2018). Three studies showed small or no effects of concurrent load (Mehta and Parasuraman, 2014; Vanden Noven et al., 2014; Cruz-Montecinos et al., 2018). In the remaining three studies, fatigue indicators were affected negatively by concurrent load (Yoon et al., 2009; Mehta and Agnew, 2012a, 2012b). Endurance time was shorter during the concurrent task compared to isometric work only in one study (Yoon et al., 2009), and decreased when a handgrip at 35% MVC was combined with an arithmetic task, compared to only handgrips at lower or higher intensities (Mehta and Agnew, 2012a, 2012b).

Performance was assessed in two studies (Mehta et al., 2012; Cruz-Montecinos et al., 2018). In both studies, performance was affected negatively by concurrent load (Mehta et al., 2012; Cruz-Montecinos et al., 2018).

Low-intensity dynamic contractions

Twenty-nine studies investigated the effects of low-intensity dynamic contractions combined with a cognitive load (Table 1). Studies in this category reported an effect of concurrent load used assembly (Shaikh et al., 2012), computer work (Finsen et al., 2001b; Leyman et al., 2004), and active workstations (Larson et al., 2015; Frodsham et al., 2020) as the physical task, while cognitive tasks were instructions necessary to accomplish the physical task (Finsen et al., 2001b; Shaikh et al., 2012), or an Auditory Verbal Learning Test (Larson et al., 2015; Frodsham et al., 2020). Among the studies reporting no or small effects of concurrent load, the most common physical task was computer work (Finsen et al., 2001a, 2001b; Leyman et al., 2004; Bloemsaat et al., 2005). Three studies used instructions needed to perform the physical task as the cognitive task (Finsen et al., 2001a, 2001b; Shaikh et al., 2012), and one used an auditory memory task (Bloemsaat et al., 2005).

Executive functions

Sixteen of the 29 studies used tests of executive functions as the cognitive load.

Studies in this category reporting a medium or large effect of concurrent load used a range of physical and cognitive tasks, for example, computer tasks (Ekberg et al., 1995; Birch et al., 2000; Alkjær et al., 2005), active workstations (Frodsham et al., 2020; Schellewald et al., 2021), and handgrip (Guillery et al., 2013); in combination with Stroop Color Word tests (Ekberg et al., 1995; Alkjær et al., 2005; Schellewald et al., 2021), visual memory tasks (Guillery et al., 2013) or instructions needed to perform the physical task (Birch et al., 2000; Nino et al., 2020). Studies reporting no or small effects typically used a physical task adopted from an occupational setting, such as pipetting (Srinivasan et al., 2015, 2016), assembly (Biondi et al., 2021), and computer work (Ekberg et al., 1995; Birch et al., 2000; Laursen, Jensen and Ratkevicius, 2001), in combination with instructions needed to perform the physical task (Srinivasan et al., 2015, 2016), n-back (Biondi et al., 2021), and Stroop Color Word tests (Ekberg et al., 1995; Laursen et al., 2002).

Biomechanical indicators were assessed in 11 studies (Ekberg et al., 1995; Birch et al., 2000; Laursen et al., 2002; Alkjær et al., 2005; Qiu and Helbig, 2012; Guillery et al., 2013; Srinivasan et al., 2015, 2016; Nino et al., 2020; Biondi et al., 2021; Marshall et al., 2021). In six of these, effects of concurrent load were absent or small (Ekberg et al., 1995; Birch et al., 2000; Laursen et al., 2002; Srinivasan et al., 2015, 2016; Biondi et al., 2021). In the remaining studies, effects were negative (Alkjær et al., 2005; Qiu and Helbig, 2012; Guillery et al., 2013; Nino et al., 2020; Marshall et al., 2021). Overall, the rated workload was higher during concurrent load (Nino et al., 2020). In one study, gait was found to be more negatively affected than cognitive performance during concurrent load (Marshall et al., 2021).

Stress was assessed in four studies (Ekberg et al., 1995; Garde et al., 2002; Alkjær et al., 2005; Srinivasan et al., 2016). Two did not find a significant effect of concurrent load (Garde et al., 2002; Srinivasan et al., 2016), and two studies found a negative effect (Ekberg et al., 1995; Alkjær et al., 2005).

One study addressed fatigue indicators (Alkjær et al., 2005), and found that the percentage of time with EMG gaps (short periods of interruptions in EMG activity, indicating muscular rest) significantly decreased during concurrent load compared to a physical reference task only.

Eight studies addressed performance (Birch et al., 2000; Alkjær et al., 2005; Ohlinger et al., 2011; Srinivasan et al., 2016; Huang et al., 2019; Frodsham et al., 2020; Marshall et al., 2021; Schellewald et al., 2021). Four studies found no significant or small effects (Alkjær et al., 2005; Ohlinger et al., 2011; Srinivasan et al., 2015; Huang et al., 2019). In three studies, performance was negatively affected by concurrent load, and effects were large (Birch et al., 2000; Marshall et al., 2021; Schellewald et al., 2021). One study found a positive effect of concurrent load, with increased task accuracy and decreased response time compared to doing only the cognitive task (Frodsham et al., 2020). Two studies showed a mixed result, where some task combinations with executive functions showed no effect, while task combinations with other executive functions influenced performance negatively (Marshall et al., 2021; Schellewald et al., 2021).

Memory recall

Nine studies addressed conditions where tests of memory recall were combined with a low-intensity physical task. The most common task combinations were active workstations combined with rey auditory verbal learning test (Larson et al., 2015; Frodsham et al., 2020) or computer tasks combined with instructions needed to perform the physical task (Finsen et al., 2001a, 2001b).

Six of the studies assessed biomechanical indicators (Finsen et al., 2001a, 2001b; Leyman et al., 2004; Bloemsaat et al., 2005; Shaikh et al., 2012; Grindle et al., 2018). In five studies, effects were small (Finsen et al., 2001a, 2001b; Leyman et al., 2004; Bloemsaat et al., 2005; Grindle et al., 2018). In the last study (Shaikh et al., 2012), perceived workload was found to be significantly higher in concurrent load conditions.

One study assessed stress indicators, and found HR and BP to increase significantly, that is, that stress increased, in response to concurrent tasks (Finsen et al., 2001a).

Fatigue was assessed in one study (Shaikh et al., 2012), which did not find any effect of concurrent load.

Performance was assessed in six studies (Leyman et al., 2004; Bloemsaat et al., 2005; Shaikh et al., 2012; Larson et al., 2015; Frodsham et al., 2020; Schellewald et al., 2021). Three studies found no or small effects of concurrent load (Bloemsaat et al., 2005; Shaikh et al., 2012; Schellewald et al., 2021), and the remaining three studies found a negative effect on performance (Leyman et al., 2004; Larson et al., 2015; Frodsham et al., 2020) with medium effects sizes.

Combined/complex processing

Eleven studies addressed conditions where combined/complex processing was used as the cognitive tasks in combination with a low-intensity physical task. The most common cognitive task was different versions of an arithmetic task (Ekberg et al., 1995; Taelman et al., 2011; Wang et al., 2011; Qiu and Helbig, 2012; Larson et al., 2015; Grindle et al., 2018; Hernández Arellano et al., 2018; Longo et al., 2018; Schellewald et al., 2021). Common physical tasks were computer work (48, 62, 75, 80, and 85) and active workstations (51 and 76).

Seven studies assessed biomechanical indicators (Ekberg et al., 1995; Hughes et al., 2007; Wang et al., 2011; Qiu and Helbig, 2012; Grindle et al., 2018; Hernández Arellano et al., 2018; Longo et al., 2018). Four of these found no or small effects (Ekberg et al., 1995; Wang et al., 2011; Grindle et al., 2018; Hernández Arellano et al., 2018). In one study, results were mixed (Hughes et al., 2007). Two studies found a negative effect of concurrent load (Qiu and Helbig, 2012; Longo et al., 2018), with medium effect sizes.

Five studies assessed indicators of stress (Ekberg et al., 1995; Kolish and Schaefer, 1996; Taelman et al., 2011; Wang et al., 2011; Hernández Arellano et al., 2018). Three studies found no or only small effects of concurrent load (Ekberg et al., 1995; Kolish and Schaefer, 1996; Hernández Arellano et al., 2018). Two studies found a negative effect of concurrent load (Taelman et al., 2011; Wang et al., 2011), with medium to large effect sizes. In one study, HR and BP were higher during concurrent load than during a baseline task (Wang et al., 2011) and in the other, indications of a decreased parasympathetic nervous activation were found in concurrent load compared to a physical task only (Taelman et al., 2011).

Fatigue indicators were assessed in one study (Wang et al., 2011), reporting that perceived physical exertion was significantly higher during a concurrent task than during the physical task alone.

Performance was assessed in six studies (Ekberg et al., 1995; Hughes et al., 2007; Larson et al., 2015;

Hernández Arellano et al., 2018; Frodsham et al., 2020; Schellewald et al., 2021). In two studies, cognitive performance was not affected by concurrent load (Hernández Arellano et al., 2018; Schellewald et al., 2021). In one study, results were mixed, as typing speed but not total errors were negatively affected by concurrent load (Hughes et al., 2007). In two studies, cognitive performance was negatively affected by concurrent load, with a medium effect size (Ekberg et al., 1995; Larson et al., 2015). In one study, scores in the cognitive task increased in the concurrent condition compared to a cognitive task only, that only, performance was affected positively by concurrent load (Frodsham et al., 2020).

Regarding well-being, one study showed that participants rated feelings of irritation, boredom, and unpleasantness to be higher during concurrent load, but only when the cognitive load was high (Kolish and Schaefer, 1996).

High-intensity dynamic contractions

We did not find any studies combining high-intensity dynamic contractions with **executive functions** or **memory recall**.

Combined/complex processing

In three studies of high-intensity dynamic contractions, tests of combined/complex processing were used as the cognitive load. Participants lifted boxes in combination with an arithmetic task in two studies (DiDomenico and Nussbaum, 2008; Katsuhira et al., 2013), and the third study used different physical tasks; elbow and knee extensions and box lifting, in combination with an arithmetic task (DiDomenico and Nussbaum, 2011).

All three studies assessed biomechanical indicators. Two studies reported no or small effects of concurrent load (DiDomenico and Nussbaum, 2008, 2011). In the last study, results were mixed, as the biomechanical load were negatively affected by concurrent loads during some working postures but unaffected in others (Katsuhira et al., 2013).

Performance was assessed in two studies (DiDomenico and Nussbaum, 2008, 2011). Both studies reported negative but small effects of concurrent load (DiDomenico and Nussbaum, 2008, 2011).

Studies of alternating physical and cognitive tasks

Six studies investigated alternating physical and cognitive tasks (Table 2).

Isometric contractions.

We found no studies addressing alternations between isometric contractions and cognitive tasks

Low-intensity dynamic contractions

We did not find any studies of alternations combining low-intensity dynamic contractions with memory recall or combined/complex processing.

Executive functions

Four studies were devoted to alternations between a low-intensity physical task and tests of executive functions. The four studies were very similar; three included pipetting and n-back (Mixter et al., 2019, 2020, 2021), and one included a repetitive reaching task and n-back (Mathiassen et al., 2014).

Three studies assessed fatigue (Mathiassen et al., 2014; Mixter et al., 2019, 2021). Two studies reported that fatigue indicators did not differ when alternating between a particular physical load and different cognitive task difficulties (Mixter et al., 2019, 2021), the third found recovery of perceived fatigue to be greater during the most difficult cognitive task, while muscle activity during work was not affected (Mathiassen et al., 2014).

Three studies addressed stress indicators (Mathiassen et al., 2014; Mixter et al., 2020, 2021). In two studies, stress indicators did not differ between protocols with different cognitive task difficulties (Mixter et al., 2020, 2021). In the third study, HRV indicated a better recovery in the protocol with the most difficult cognitive task (Mathiassen et al., 2014).

The three studies also addressed performance, and did not find performance to change over time at any of the cognitive difficulty levels (Mathiassen et al., 2014; Mixter et al., 2019, 2021).

High-intensity dynamic contractions

We did not find any studies alternating high-intensity dynamic contractions with the test of **memory recall.**

Executive functions

One study examined high-intensity dynamic contractions, that is, a lifting task, alternating with a cognitive task mainly requiring executive functions (instructions required to perform the physical task) (Davis et al., 2002).

The study assessed biomechanical indicators, and found that alternation resulted in minor increases in trunk muscle activity compared to concurrent cognitive and physical tasks, where decisions had to be made during the lifting task (Davis et al., 2002).

Combined/complex processing

One study addressed a lifting task engaging either the elbow or finger flexors, alternating with an arithmetic task (Asmussen and Mazin, 1978), and reported performance to increase, that is, that the amount of physical work that could be performed after a 'break; including an arithmetic task was greater than after a passive break.

Discussion

In this systematic review, we summarize and synthesize studies investigating the effects of combining occupationally relevant physical and cognitive tasks. In close collaboration with an information specialist, we performed a systematic search based on a comprehensive search string and generous inclusion criteria regarding exposure as well as outcomes. The literature search resulted in 11 324 records, which were boiled down to 61 relevant studies. Our quality screening resulted in four studies being excluded because of low quality, thus leaving 57 studies as our final evidence base. We are fairly certain to have captured the majority of studies of sufficient quality that assess effects of combining physical and cognitive work tasks, compared with doing only one of these tasks. As far as we know, this is the first systematic review to address combinations of physical and cognitive work tasks in an occupational context.

Overall, performing a concurrent physical and cognitive task appears to have a negative, yet numerically small, effect on biomechanical indicators, fatigue, and performance. For stress indicators, results were less clear. Only few studies addressed indicators of well-being and conclusions regarding that outcome were not justified. It must be stressed, however, that studies, even if placed in a particular category of combination between physical and cognitive load (cf. Tables 1 and 2), differed vastly in terms of design, the tasks combined, and the duration and time pattern of exposure. In addition, many studies reported nonsignificant, small, or marginal effects, which makes it difficult to draw any conclusions. We were not able to verify the positive distraction effects of a mental task on performance and fatigue (Blanchfield et al., 2014; Grande-Alonso et al., 2020).

Effects of concurrent load appear to differ between different types of physical exertion (e.g. which muscles were engaged) and physical exertion levels and types of exertion (e.g. the engaged muscles). In one study, for example, HRV was only affected by a concurrent cognitive task during a low-intensity physical task (5% MVC) but not during higher intensities, and only during wrist and torso exertions but not when the deltoid was used (Mehta et al., 2012). The authors suggest that the effect of concurrent loads might be task-specific (Mehta et al., 2012). In another study, negative effects on perceived workload were only found during concurrent load with shoulder exertions, and not with other types of physical exertions (Mehta and Agnew, 2015). Some studies in this review indicate that concurrent load may lead to a redistribution of activity within and between muscles compared to physical-only tasks, and the muscles in the neck/shoulder region seem to be more sensitive to concurrent protocols than extremity muscles (Bloemsaat et al., 2005; Au and Keir, 2007). This, in turn, appears consistent with the trapezius muscle being more susceptible to psychosocial stressors than the extremity muscles (Waersted and Westgaard, 2010; Shahidi et al., 2013).

In the six studies devoted to alternating physical and cognitive tasks, four reported that a low-intensity dynamic task alternating with an executive function task could be performed with physical recovery taking place during the cognitive task periods (Mathiassen et al., 2014; Mixter et al., 2019, 2020, 2021). Performance was also maintained over time, even with a quite difficult cognitive task (Mathiassen et al., 2014; Mixter et al., 2019, 2020, 2021). One study comparing concurrent and alternating tasks reported that spine loading was less in an alternating protocol than when tasks were performed concurrently (Davis et al., 2002). Another study even showed a positive effect of alternations, in that participants were able to perform more physical work after a "break" including an arithmetic task than after a passive break (Asmussen and Mazin, 1978). This effect may be due to effects in the central nervous system, with a diverting activity accelerating recovery from physical fatigue, irrespective of whether that activity is cognitive or physical (Sechenov, 1935; Asmussen and Mazin, 1978).

Although studies of alternating tasks were too few to justify any general conclusions, we did not find any objections to the idea that alternations would be an attractive option for designing jobs in occupational practice.

Strengths and limitations of the included articles

Selection bias

A majority of the studies in this review were conducted on quite young populations (most studies included subjects 20–30 years of age), and results may not be representable for other age groups. In nearly half of the 57 reviewed studies, participants were students or were reported to be recruited from the university community. Studies suggest that older subjects exhibit larger force fluctuations during concurrent tasks than younger (Pereira et al., 2015), and that performance in both the physical and cognitive tasks differs according to age in concurrent task protocols (Voelcker-Rehage et al., 2006). In some studies comparing the effects of concurrent tasks between younger and older subjects, the older participants were older than allowed by our inclusion criterion, and the studies cannot be used to conclude on the effects of age among subjects of working age.

Study design

A vast majority of the studies applied a within-subject repeated-measures design, allowing control of confounders and offering a better statistical power than studies comparing independent groups. Most included studies described the order of study sessions as counterbalanced between participants, thus controlling for learning effects. In some studies, however, all conditions were presented during the same study session, which could increase the risk of carry-over effects. Of note, a blinded design is not possible in studies requiring participants to do different work tasks, and we did not assess study quality in this aspect.

Ecologic validity

The present review included only controlled experimental studies. Laboratory experiments have the advantage over working conditions in being possible to manipulate according to the decisions of the researcher, without 'contamination' by external factors. This minimizes confounding, and also allows for outcomes to be measured using methods that may not be feasible outside the laboratory. The disadvantage is that these controlled working conditions may be a too strict model of actual exposures in occupational life, including that some occupational conditions may not be possible to model in a laboratory, and that short-term outcomes may be difficult to interpret in the context of long-term effects.

In the present review, we aimed to include tasks of occupational relevance. We deliberately chose to exclude 'extreme' physical tasks, such as tasks requiring high physical exertion (Epling et al., 2016) and other physical tasks performed in extreme environments (Bhattacharyya et al., 2017). While we acknowledge that such work tasks are performed by some parts of the work force, such as military and police staff, they are not usually performed by the working population. Several tasks in the reviewed studies, such as pipetting, assembly work, and computer work, were replicas of tasks performed in occupational settings (Björksten et al., 1994; Nordander et al., 2004; Lintula and Nevala, 2006). Other tasks may be viewed as crude models of occupational tasks. Thus, truly isometric, isotonic tasks are, for instance, very rare in occupational settings. On the other hand, isometric tasks are easy to standardize and manipulate, and can provide valuable information about the effects of performing physical tasks at different intensities, and by different muscles. In combination with a cognitive load, this may also lead to results regarding possible interaction effects between physical exertion levels and the type and complexity of the cognitive task. However, responses to isometric tasks may differ considerably from responses to dynamic tasks at the same level of exertion (Frey Law et al., 2010), and results from isometric studies need to be interpreted with caution. The other two physical task categories (low-intensity dynamic contractions and high-intensity dynamic contractions) may share more similarities with real occupational tasks.

Regarding the cognitive task, we chose to not include studies comprising 'external' cognitive demands, or stressors that were not an explicit part of the cognitive task demands. For instance, some studies addressed surveillance from examiners and negative and unpleasant feedback during the experiment to evoke stress (Blangsted et al., 2004; Hjortskov et al., 2004) and were therefore excluded. While we acknowledge that such factors will inevitably influence the work environment in real occupational settings, our aim was to investigate the effects of combinations of predominantly physical tasks and predominantly cognitive tasks *per se*; not external psychosocial stressors that were not an integrated part of the tasks.

We formed three categories of cognitive tasks, that is, executive functions, memory recall, and complex/combined processing. Obviously, these categories are somewhat arbitrary. For example, all cognitive processes involve some extent of executive functioning (e.g. the ability to inhibit irrelevant stimuli). However, the tasks categorized in each group do share common processes. While we realize that the three categories could have been divided into further subcategories, this approach would possibly make it more difficult to identify effects of combinations.

Another issue of relevance to ecological validity concerns the strict division of physical and cognitive tasks in the studies included in this review. This strict division may not correspond to work tasks in real occupational settings, where work tasks are often seen as 'predominantly cognitive' or 'predominantly physical' (Jahncke et al., 2017). In addition, experience in performing a physical or a cognitive task influences how much effort the individual eventually needs to invest in the task (Halsband and Lange, 2006), and an experienced worker may well differ in responses from the often less experienced subjects participating in a controlled study.

To this end, many studies included in this review did not have an explicit aim of investigating occupationally relevant tasks, but rather combined tasks that would likely cause a pronounced response. For instance, arithmetic tasks, even single-digit tasks, are considered to be complex in that they require multiple executive functions to be used (DeStefano and LeFevre, 2004), but their relevance in an occupational context may be questioned. Thus, some of the cognitive tasks in the reviewed studies may have been designed to challenge participants' cognitive capacity to an extreme extent that would, for reasons of productivity and work satisfaction, not occur in an ordinary occupational setting. We were, however, liberal in our interpretation of 'occupationally relevant,' and especially so for the cognitive tasks, to include even studies that could indicate the direction in which outcomes might be changed by tasks more extreme than what can be found in real occupational settings.

Implications for working life

Most studies in this review reported that concurrent physical and cognitive tasks lead to negative effects compared to physical-only tasks. As mentioned earlier, several studies also reported negative, yet insignificant, small or marginal effects. Since tasks in the studies included in this review were performed only for a short period of time—some hours at the most—this raises the question of how biomechanical exposures, stress, fatigue, performance, and well-being would be affected if combinations were performed for days, months, or years. Small effects may not be an issue in real occupational settings if the worker adapts to concurrent tasks performed for a long time, but if an adaptation does not occur, they may influence health negatively due to a cumulated effect over time. Repetitive work tasks at a low intensity may cause accumulated fatigue over time, which can lead to musculoskeletal disorders (Bosch et al., 2007; Nordander et al., 2009), especially in combination with psychosocial stress (Lundberg et al., 1999). This is consistent with the allostatic load model, emphasizing that repeated loads may, over a long time, lead to a maladaptive stress response if recovery is not sufficient (McEwen, 2004). To the best of our knowledge, very few studies have addressed the effects of combined physical and cognitive load in naturalistic settings over a long time. In one study, workers with both mental and physical demands had higher baseline cortisol excretion than workers with predominantly physical *or* predominantly mental work (Sluiter et al., 2000). However, workers representing combined demands were mainly ambulance workers, and results may be confounded by this group being exposed to considerable emotional demands.

Regarding effects of alternations between physical and cognitive tasks, general conclusions are not justified, due to the small number of controlled studies. Of note, though, we did not find any studies reporting a negative effect on any outcome of introducing a cognitive task, even if it was difficult, in-between physical work bouts, compared to alternating the physical task with a passive break or a very easy cognitive task. One study even suggested that alternations could have a positive influence on recovery from fatigue (Asmussen and Mazin, 1978). Although the long-term effects of alternations have not been examined, the absence of acute negative effects appears comforting in an occupational context. We also emphasize that workers may prefer to alternate between physical and cognitive tasks rather than performing only one of them (Jahncke et al., 2017), and that motivational factors are important when considering alternations between work tasks. Studies of quite intense physical tasks have suggested that a lack of motivation may cause an earlier onset of fatigue (Enoka and Stuart, 1992). Furthermore, stress regulation is sensitive to cognitive appraisal (Thackray and Pearson, 1968; Gaab et al., 2005); work tasks considered to be too difficult or too stressful may lead to impaired stress regulation over time, while work tasks considered to be meaningful and positively challenging may promote workers' health. Thus, we see alternations between physical and cognitive tasks as a viable alternative for job rotation, which may overcome limitations in most previous attempts to accomplish a rotation leading to sufficient physical variation for the individual worker (Leider et al., 2015; Padula et al., 2017).

Experimentally controlled studies with the aim to investigate the effects of task combinations provide a knowledge base for future studies in the field (van der Beek et al., 2017), and we emphasize that such studies should address arrangements of work tasks that can sustain workers' health. Thus, the next step would be to design epidemiologic field studies or interventions that can evaluate effects of combinations in the long term, and, more specifically, address how the intensity and time pattern of physical and cognitive loads affects health and well-being.

Conclusions

Based on this review, we conclude that concurrent physical and cognitive work tasks have negative, if numerically small, effects on biomechanical indicators, fatigue, and performance, compared to performing the physical task alone. For stress outcomes, results were mixed. Very few studies included well-being as an outcome. However, the reviewed laboratory studies report short-term effects of concurrent load and it is not possible to draw any firm conclusions on long-term effects in occupational life. If concurrent tasks have to be performed in working life, employers should, however, likely strive for both the physical and the cognitive tasks to pose moderate demands. Regarding alternating tasks, evidence is insufficient due to the small number of studies. However, alternating between physical and cognitive tasks has been proposed as an alternative to classic job rotation (manipulating predominantly physical tasks), and the results of the present review do not oppose further development of such initiatives.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the conclusions, implications or opinions reported in this paper.

Data availability

Data sharing is not applicable to this article as no datasets were generated during the current systematic review.

Supplementary data

Supplementary data are available at *Annals of Work Exposures and Health* online.

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