How does occupational physical activity influence health? An umbrella review of 23 health outcomes across 158 observational studies

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ABSTRACT

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Objective Physical activity (PA) has substantial benefits across a range of health outcomes. There is uncertainty about the PA-specific health effects, and in particular, the occupational domain. In this umbrella review, we synthesised available evidence on the associations between occupational PA (OPA) and health-related outcomes (including cancer, all-cause mortality and cardiovascular disease). This work informed the development of WHO's guidelines on PA and sedentary behaviour (2020).

Design Umbrella review of systematic reviews. **Data source** We performed a literature search in PubMed, Web of Science, Embase, CINAHL and Sportdiscuss from database inception to 2 December 2019.

Eligibility criteria for selecting studies We

included systematic reviews if they contained a quantitative assessment of OPA and its relationship with at least one health-related outcome.

Results We summarised the evidence of 17 reviews covering 23 unique health-related outcomes. We graded most evidence as low or very low, or moderate quality. We found health benefits for those engaging in high versus low OPA for multiple cancer outcomes (including colon and prostate), ischaemic stroke, coronary heart disease and mental health (ie, mental well-being and life satisfaction). High OPA was associated with unfavourable health outcomes for all-cause mortality in men, mental ill health (ie, depression and anxiety), osteoarthritis, and sleep guality and duration.

Conclusions We found favourable associations for most health-related outcomes with high OPA levels. but we also found some evidence for unfavourable associations due to high OPA levels. At this point, there is a need for better quality evidence to provide a unequivocal statement on the health effects of OPA.

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INTRODUCTION

Physical activity (PA) has significant health benefits and contributes to the prevention of a range of lifestyle-related, non-communicable diseases.¹ Physical inactivity is one of the global leading risk factors for all-cause mortality.³ Both national and international PA guidelines for adults, including the 2010 guidelines by WHO, recommend at least 150 min per week of moderate-intensity PA.¹² The Global Action Plan on PA highlighted the need to update the 2010 WHO Global recommendations

on PA for Health.⁴ WHO published the guidelines on PA and sedentary behaviour in 2020, further details of which can be found in the current issue of BISM.⁴

The 2010 WHO PA guidelines did not differentiate between domains of PA (work, commuting, household and leisure), suggesting comparable health benefits for all these PA domains.² Most studies reviewed by the 2010 guidelines were restricted to leisure-time PA (LTPA) domain,² and evidence on domain specific health benefits was largely inconclusive. Differential health effects have been reported for LTPA and occupational PA (OPA),⁵⁻⁷ a phenomenon which is referred to as the PA paradox.⁸ For example, a prospective cohort study showed that LTPA was associated with reduced risk of all-cause mortality, while OPA was associated with an increased risk of all-cause mortality.⁶ It is not clear whether these differential associations are due to domain-specific PA characteristics (eg, differences in posture, intensity level, frequency, duration and/or recovery time between OPA and LTPA⁸) or down to methodological reasons.^{9 10}

As the amount of systematic reviews and metaanalyses accumulates,¹¹ more advanced evidence synthesis methods such as umbrella reviews can be employed.¹² An umbrella review provides a broader picture of findings for a particular question or phenomenon, and is therefore useful to inform guidelines.¹² PA-related umbrella reviews are mostly restricted to LTPA only,^{13–15} with no umbrella review on the health effects of OPA currently.

In this umbrella review, we aimed to provide an overview on the relationships between OPA and a range of health-related outcomes, including cancer, cardiovascular disease (CVD) and all-cause mortality. We also aimed to assess dose-response relationships and whether the relationship between OPA and health differs from that of LTPA.

This review builds on a report on OPA commissioned by WHO to inform the guidelines on PA and sedentary behaviour (2020).

METHODS Literature search

This protocol was registered in PROSPERO (id: 163090).¹⁶ We searched in PubMed, CINAHL, Web of Science, Embase and Sportdiscuss from database inception up to 2 December 2019 for systematic



reviews assessing the relationship between OPA and healthrelated outcomes. Searches contained keywords covering OPA, systematic reviews and meta-analyses. See online supplemental material table 1 for a detailed outline of the search strategy. We identified additional reviews by screening the reference list of included reviews and by consulting experts. Two reviewers (BC and ML) independently screened title, abstract and full text of identified references using the online Rayyan application (rayyan.qcri.org).¹⁷ Discrepancies between the two reviewers were resolved in a consensus meeting, or by consulting a third reviewer (PC).

Review inclusion and data extraction

We included full-text systematic reviews of observational (eg, cohort, case–control, cross-sectional) and experimental studies (eg, (randomised) controlled trials) written in English. Reviews had to contain a quantitative assessment of OPA and an association with at least one health-related outcome considered relevant by WHO PA guideline advisory committee. See the full list of outcomes considered in online supplemental material table 2. We excluded articles if the OPA domain was not specifically assessed. We also excluded reviews if they focused on sedentary behaviour only or on biomechanical exposures only (ie, lifting or prolonged postures such as standing or kneeling), without considering energetic components of OPA. We excluded reviews focused on specific (clinical) populations, such as pregnant women or cohorts with an disease.

One reviewer (BC) extracted data from included reviews, which was checked by a second reviewer (ML). Potential conflicts were discussed until consensus was reached. We extracted first author, title, year of publication, outcome, study design, number of included studies, comparison group and effect sizes. If available, effect sizes of LTPA were also extracted.

Methodological quality and certainty of evidence

We rated included systematic reviews using A MeaSurement Tool to Assess systematic Reviews2 (AMSTAR2),¹⁸ a 16-point tool for assessment of the methodological quality of systematic reviews, with good inter-rater agreement, test–retest reliability and content validity.¹⁹ Review quality could be high, moderate, low or critically low, with cut-off values of 100%, \geq 75%, \geq 50% and <50%, respectively. One reviewer (BC) assessed methodological quality; the second reviewer (ML) checked these assessments. If reviews were rated critically low, they were excluded from further analyses.

We used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) method²⁰ to rate the quality of evidence for each of the health-related outcomes. The GRADE system rates the quality of evidence as:

- ► High quality: further research is very unlikely to change our confidence in the estimate of effect.
- Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
- ► Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
- ▶ Very low quality: any estimate of effect is very uncertain.²⁰

The starting point for the quality of the evidence was 'high'.^{21 22} We decreased this grading if the reviews showed: risk of bias (ie, selection, performance, detection, attrition and/ or reporting bias), inconsistency of results (ie, unexplained heterogeneity or I²-statistics \geq 50%), indirectness of evidence

(ie, differences in populations, intervention, outcome measures or indirect comparisons), imprecision (ie, 95% CI includes 1.0) or publication bias (asymmetry in funnel plot). We increased the rating by one level if there was a large magnitude of the effect (eg, RR or OR ≥ 2.0 or ≤ 0.5), in case of plausible confounding (which may have reduced an observed effect), or in case of a dose–response gradient.²³

Data analysis

If more than one review reported on a certain outcome, we only used the most recently published review (typically with the highest number of included studies) for further analyses; unless a less recent review reported higher certainty of evidence (GRADE). Online supplemental material table 3 enumerates the included studies for main and sensitivity analyses. If subgroup analyses (eg, regarding higher quality evidence or different study designs) were provided with different GRADE scores, then evidence from the highest GRADE score was synthesised. We constructed forest plots to display the relationship of high vs low OPA with health-related outcomes. We conducted sensitivity analyses to assess consistency of the synthesised evidence if there was more than one review for the same outcome.

If the original review had estimated the I² statistics, we synthesised this information to assess heterogeneity.²⁴ If reviews did not publish the I² statistics, we calculated this where possible.

We synthesised small-study bias or publication bias (when referring to OPA studies). Whenever a review did not provide this information, and included more than ten OPA studies we reanalysed the data and provided funnel plots to assess publication bias on visual inspection. In case no information was provided and less than 10 studies were available, we considered the review at stake to be 'at risk of bias' since a funnel plot would be inaccurate with fewer than 10 studies.²⁵

If available, we provided dose–response relationships from reviews that had reported on more than two categories of OPA or on a continuous OPA scale. For the comparison of the relationships of OPA and LTPA with health, we only used already included reviews that reported on both OPA and LTPA. Differences between the effect sizes of OPA and LTPA were statistically tested²⁶ using a test of interaction. All analyses were conducted using Revman V.3.5.3.

RESULTS

The literature search generated 573 references. After removing duplicates and adding seven reviews from snowball searching, we screened 312 references by title and abstract (figure 1). Full texts of 73 reviews were screened, of which we excluded 37 reviews for various reasons (online supplemental material table 4).

We identified 36 reviews that examined the associations between OPA and 23 unique health-related outcomes.²⁷⁻⁶² The most frequently reported outcome was cancer, with 11 different cancer types (24 reviews). Other reviews evaluated CVD (n=3), osteoarthritis (n=3), all-cause mortality (n=2), hypertension (n=1), diabetes mellitus type 2 (n=1), insomnia (n=1) and mental health (n=1) (online supplemental material table 3). We did not detect any reviews on adiposity, cognitive outcomes or health-related quality of life.

Quality assessment

AMSTAR2 scores for methodological quality of the 36 included reviews are shown in online supplemental material table 5. Six reviews scored (17%) critically low which we did not use for further analyses.^{30 32 35 49 55 59} Eight reviews (22%) scored



Figure 1 Flow chart depicting the review search and selection procedure. OPA, occupational physical activity.

moderate, and 22 (61%) scored low methodological quality. None of the included reviews scored high on the AMSTAR2 scale, with common methodological issues for example being lack of a priori protocol registration (only done in four reviews), not reporting a comprehensive search strategy (only performed in ten reviews) and not providing a list of excluded studies (only done in five reviews).

Evidence synthesis

Online supplemental material table 6 presents extracted data. Seventeen reviews (on 23 unique outcomes) were synthesised. These reviews reported on 158 studies: 96 (61%) longitudinal cohort studies, 60 (38%) case–control studies and 2 (<1%) cross-sectional studies, while no reviews on experimental studies met the inclusion criteria. Reviews described between three and 27 individual studies, with a median of 7.5 studies per review. We did not synthesise thirteen reviews because there was a more recent published review, or a review with a higher certainty of evidence (online supplemental material table 3).

Grading of Recommendations Assessment, Development and Evaluation

We graded none of the included reviews as high quality; overall the evidence was of moderate quality at best (online supplemental material table 6). Four reviews (17%) on colon cancer, rectal cancer, endometrial cancer and prostate cancer provided moderate quality evidence. Reviews of nine (39%) outcomes provided low quality evidence (all-cause mortality, ischaemic stroke, coronary heart disease (CHD), proximal and distal colon cancer, breast cancer, gastric cancer and renal cancer) and ten other reviews (43%) offered very low-quality evidence.

PA measurement methods varied across reviewed studies, and included self-administered questionnaires, interviews or job titles. Because PA was mostly self-reported, misclassification was reported in almost all included reviews. In some reviews PA was assessed at baseline, but a change in PA over time was not considered. Over half of the reviews reported that there was confounding bias, that the adjustment of variables widely varied between studies, or that important confounding variables were not addressed in reviewed studies. Some review reported language bias; typically only one or two languages were included in the reviews.

Of the 23 health outcomes, 14 (61%) reported an I² statistics < 50% and seven (30%) reported an I² statistics \geq 50% (hypertension, mental health, mental ill health, stroke, all-cause mortality, poor sleep duration and/or quality and osteoarthritis). For two outcomes (oesophageal and endometrial cancer) the reviews did not provide I² statitics. Re analysis showed a low heterogeneity $(I^2=0\%)$ for endometrial cancer and considerable heterogeneity for oesophageal cancer (I²=89%) (online supplemental material figure 7). Most reviews were precise; the risk estimates of only seven (30%) outcomes had 1.0 included in their 95% CI. Although all 17 reviews used the Eggers asymmetry test to detect publication bias, in most reviews, the association between OPA and a health-related outcome was investigated in a subgroup analysis on OPA only, with the Egger test conducted for 'total PA' (including OPA). Only for four outcomes (17%) (in three reviews) a test for publication bias was conducted, addressing the OPA domain. Only one of these three reviews found a small risk for publication bias. It is likely that reviews did not conduct separate analyses because there were not enough unique OPA studies included: fourteen (61%) outcomes included less than 10 studies on OPA. We reanalysed the data of four outcomes and did not detect publication bias in these reviews (online supplemental material figure 8). One review included more than ten studies, but did not report individual study effect sizes, hence we could not perform an assessment of publication bias.⁴

Evidence

All synthesised reviews are summarised in figure 2, with quality of the evidence ranging from moderate to very low.

Moderate quality evidence

A meta-analysis of Mahmood *et al*³³ including five cohort and ten case-control studies showed a statistically significant reduction in risk of colon cancer among those with high compared with low OPA (RR 0.74, 95% CI 0.67 to 0.82). This association was comparable for men (RR 0.74, 95% CI 0.66 to 0.82) and women (RR 0.78, 95% CI 0.65 to 0.93). In the same review, authors presented pooled estimates regarding the association between OPA and rectal cancer from five cohort and seven case–control

GRADE	First author	Outcome ¹	Total studies	Estimate	Decreased	Increased	l ² %	Publication
			(cohort)		Risk	Risk		bias
Moderate	Mahmood (33)	Colon cancer	15 (4)	0.74 (0.67-0.82)	+		34	No ³
Moderate	Mahmood (33)	Rectal cancer	12 (4)	0.88 (0.79-0.98)	+-		23	No ³
Moderate	Schmid (41)	Endometrial cancer(F)	19 (9)	0.81 (0.75-0.87)	+		0 ³	No ³
Moderate	Liu (52)	Prostate cancer(M)	27 (9)	0.86 (0.78-0.94) ²	+	1 months	16 ²	No
Low	Coenen (28)	All-cause mortality(M)	18 (18)	1.18 (1.05-1.34)		_	76	No
Low	Coenen (28)	All-cause mortality(F)	11 (11)	0.90 (0.80-1.01)		-	0	No
Low	Wendel-Vos (29)	Ischaemic stroke	6 (6)	0.57 (0.43-0.77)	—		16	Yes
Low	Sattelmair (31)	CHD	4 (4)	0.84 (0.79-0.90)	+		0	Yes
Low	Robsahm (36)	Proximal colon-cancer	5 (5)	0.59 (0.53-0.66)			0	Yes
Low	Robsahm (36)	Distal colon-cancer	5 (5)	0.61 (0.53-0.70)			29	Yes
Low	Pizot (38)	Breast cancer(F)	11 (11)	0.88 (0.82-0.95)	-+-		29	Yes ⁴
Low	Chen (39)	Gastric cancer	7 (3)	0.79 (0.65-0.95)			0	Yes
Low	Behrens (47)	Renal cancer	11 (11)	0.91 (0.79-1.04)		-	21	No ³
Very low	Wendel-Vos (29)	Total stroke	9 (9)	0.74 (0.49-1.12)		-	66	Yes
Very low	Vermaete (42)	Lymphoma cancer	5 (1)	0.98 (0.80-1.12)		-	0	Yes
Very low	Behrens (47)	Esophageal cancer	6 (1)	0.91 (0.47-1.81)			89 ³	Yes
Very low	O'Rorke (53)	Pancreatic cancer	4 (4)	0.75 (0.59-0.96)			0	Yes
Very low	Aune (56)	T2D	3 (3)	0.85 (0.79-0.92)			0	Yes
Very low	Mcwilliams (57)	Osteoarthritis	8 (2)	1.45 (1.20-1.76)			77	Yes
Very low	Yang (61)	Sleep quality	7 (3)	2.76 (1.71-4.45)		-	→ 88	No
Very low	Huai (62)	Hypertension	6 (6)	0.93 (0.81-1.08)	-+	-	66	Yes
Very low	White (60)	Mental health	5 (0)			-	77	Yes
Very low	White (60)	Mental ill-Health	8 (0)		Т I		96	Yes
CHD= Coro	nary Heart Disease, 1	0.5 0.7	1 1.5	2				

1: (F)= Female population only, (M)=Male population only, all other studies included both genders

2: Only results from 13 high quality studies were presented

3: Not published in the original review, but re-analyzed (see supplementary file 7 and 8).

4: Unable to re-analyze because no separate risk estimates were provided in the original review.

An arrow indicates that the effect size is larger than the range of the figure.

Figure 2 Forest plot depicting the evidence for the association of occupational physical activity and health. (1) (F)= Female population only, (M)=Male population only, all other studies included both genders. (2) Only results from 13 high-quality studies were presented. (3) Not published in the original review, but reanalysed (online supplemental files 7 and 8). (4) Unable to reanalyse because no separate risk estimates were provided in the original review. An arrow indicates that the effect size is larger than the range of the figure. CHD, coronary heart dsease; GRADE, Grading of Recommendations Assessment, Development and Evaluation; TD2, diabetes mellitus type 2.

studies, showing a reduced risk in those with high compared with low OPA (RR 0.88, 95% CI 0.79 to 0.98). Another systematic review that investigated colon cancer subtypes, found comparable effects for proximal (RR 0.72, 95% CI 0.61 to 0.85) and distal colon cancer (RR 0.75, 95% CI 0.63 to 0.88).³⁶ In our sensitivity analysis, comparable associations were found for both colon cancer (and subtypes) and rectal cancer.³⁴

A review on seven cohort and twelve case–control studies found a statistically significant risk reduction of endometrial cancer for women with high compared with low OPA (RR 0.81, 95% CI 0.75 to 0.87).⁴¹ Another review showed comparable results.⁴⁰

A review by Liu *et al*⁵² showed that OPA was significantly related with a reduced risk of prostate cancer (RR 0.81, 95% CI 0.73 to 0.91). The reduction in risk was statistically significantly lower for nine cohort studies (RR 0.91, 95% CI 0.87 to 0.95) compared with eighteen case–control studies (RR 0.73, 95% CI 0.62 to 0.87). When stratified for study quality, the higher quality studies showed a lower reduced risk (RR 0.86, 95% CI 0.78 to 0.94) compared with lower quality studies (RR 0.75, 95% CI 0.89 to 1.00). A statistically significant protective effect of OPA only existed in those studies in which the median follow-up duration was >10 years. Comparable results were found in other systematic reviews.⁵⁰⁵¹

Low-quality evidence

In the most recent systematic review,²⁸ men with high level OPA experienced a statistically significant increased risk of all-cause mortality (HR 1.18, 95% CI 1.05 to 1.34), even after adjusting for possible confounders, such as LTPA. A non-significant reduced risk was observed among women (HR 0.90, 95% CI 0.80 to 1.01). Authors reported considerable heterogeneity in

the pooled study findings for men (I² statistic=76%), but not for women (I² statistic=0%), and some risk of publication bias was discussed by the authors. An earlier review, with a lower number of included studies, showed a reduction in mortality risk for both genders²⁷ (RR 0.66, 95% CI 0.49 to 0.89 and RR 0.94, 95% CI 0.75 to 1.19, for females and males, respectively). In the this review, high heterogeneity was reported.

A higher level OPA was related to a lower risk of stroke; although, this association was not statistically significant for total stroke (RR 0.74, 95% CI 0.49 to 1.12).²⁹ In the association between OPA and ischaemic stroke, statistically significant protective effects were found for high vs low OPA (RR 0.57, 95% CI 0.43 to 0.77).

Sattelmair *et al* showed, based on evidence from four studies with low heterogeneity, that high versus low OPA was related to a statistically significant reduced risk of CHD (RR 0.84, 95% CI 0.79 to 0.90).³¹ Three out of four studies were based on male samples only (RR 0.87, 95% CI 0.81 to 0.99).

Pizot *et al* observed that high OPA versus low OPA was related to a statistically significantly reduced risk of breast cancer in a female population (RR 0.88, 95% CI 0.82 to 0.95).³⁸ These results were based on eleven cohort studies with low heterogeneity. Two other reviews showed comparable results.^{37 39}

Chen *et al* showed that high versus low OPA had a statistically significantly lower risk of gastric cancer (RR 0.79, 95% CI 0.65 to 0.95).⁴⁵ Behrens *et al* observed a statistically non-significant association between OPA and oesophageal cancer (RR 0.91, 95% CI 0.46 to 1.81).⁴⁶ Two other reviews found comparable results.^{43 44}

Behrens *et al* found that high versus low OPA was related to a statistically non-significant reduction in renal cancer (RR 0.91, 95% CI 0.79 to 1.04). The authors estimated these results from data of six cohort and five case–control studies⁴⁷ with low heterogeneity. Another review showed comparable results.⁴⁸

OPA showed no association with lymphoma (OR 0.98, 95% CI 0.80 to 1.02) from a review with one cohort and four case–control studies.⁴²

One review reported on the association between OPA and pancreatic cancer.⁵⁴ Three cohort studies showed a statistically significant reduction (RR 0.75, 95% CI 0.58 to 0.96). There was low heterogeneity between the included studies.

Three cohort studies with over 9000 diabetes mellitus type 2 cases showed a lower risk on this outcome (RR 0.85, 95% CI 0.79 to 0.92) for people with high versus low OPA.⁵⁶

Pooled results from two cohort, three cross-sectional and three case–control studies showed that high OPA was related with a statistically significant higher risk of knee osteoarthritis (OR 1.45, 95% CI 1.20 to 1.76).⁵⁷ Authors of this review reported high heterogeneity and a high likelihood of publication bias. Cohort studies showed lower risks compared with cross-sectional and case–control studies. Another review showed that cumulative physical workloads were associated with hip osteo-arthritis in men; this review showed mixed evidence for physical demands and knee osteoarthritis, hip osteoarthritis and osteoarthritis in multiple other joints.⁵⁸

For high versus low OPA, there was an statistically significant increased risk of insomnia (OR 2.76, 95% CI 1.71 to 4.45),⁶¹ with pooled results from four cross-sectional and three cohort studies, and high heterogeneity.

In comparison with low OPA, high OPA was related with a decreased, but statistically non-significant, risk of hypertension

(RR 0.93, 95% CI 0.81 to 1.08).⁶² The heterogeneity among six studies was high.

OPA had a weak positive association with mental ill-health (ie, depression and anxiety) (r 0.10, 95% CI 0.04 to 0.16), but also a weak positive association with mental health (ie, mental wellbeing and life satisfaction) (r 0.02, 95% CI -0.09 to 0.12).⁶⁰ Both effects showed high heterogeneity.

Health effects of occupational versus LTPA

In the included reviews, effect sizes of seventeen outcomes were available for both OPA and LTPA (figure 3). Effect sizes of both OPA and LTPA generally pointed into the same direction, with some differences in estimates provided for OPA and LTPA. The association between OPA and LTPA was statistically significant different for CHD, distal colon cancer and diabetes mellitus type 2. We could not compare OPA and LTPA for all-cause mortality, sleep quality and/or duration, osteoarthritis and mental (ill) health, because LTPA was not included in the reviews for these outcomes.

Dose–response associations

Only five outcomes, presented in three reviews, reported on dose-response associations (figure 4). Three outcomes (stroke, ischaemic stroke and hypertension) showed a gradual risk increase across three groups of OPA (high, moderate, low levels of OPA). For total stroke, the lowest risk reduction was shown for the moderately active vs inactive workers (RR 0.64, 95% CI 0.48 to 0.87). For ischaemic stroke, the most active workers

Outcome	Author (ref)	PA	Number of studies	Estimates	Decreased risk	Increased risk
Colon Cancer	Mahmood (33)	OPA	15	0.74 (0.67-0.82)		
	2017	LTPA	14	0.80 (0.71-0.90)		
Rectal Cancer	Mahmood (33)	OPA	12	0.88 (0.79-0.98)		+
	2017	LTPA	9	0.87 (0.75-1.01)		
Endometrial Cancer	Schmid (41)	OPA	19	0.81 (0.75-0.87)	-+	
	2015	LTPA	22	0.84 (0.78-0.91)	-+-	
Prostate Cancer	Liu (52)	OPA	27	0.86 (0.78-0.94)	-	
	2011	LTPA	34	0.95 (0.90-1.01)	-	┡
Ischaemic stroke	Wendel-Vos (29)	OPA	6	0.57 (0.43-0.76)		
	2004	LTPA	11	0.79 (0.69-0.91)		
CHD	Sattelmair (31)	OPA	4	0.84 (0.79-0.90)*		
	2011	LTPA	26	0.74 (0.70-0.79)*	+	
Proximal colon	Robsahm (36)	OPA	5	0.59 (0.53-0.66)		
	2013	LTPA	13	0.53 (0.44-0.64)	-	
Distal colon	Robsahm (36)	OPA	5	0.61 (0.53-0.70)*		
	2013	LTPA	13	0.40 (0.30-0.53)*	←	
Breast cancer	Pizot (38)	OPA	11	0.88 (0.82-0.95)	+	
	2015	LTPA	30	0.87 (0.84-0.91)	+	
Gastric cancer	Chen (39)	OPA	7	0.79 (0.65-0.95)		-
	2014	LTPA	7	0.89 (0.74-1.06)	-	+
Renal cancer	Behrens (47)	OPA	11	0.91 (0.79-1.04)		-
	2013	LTPA	19	0.88 (0.77-1.00)	-+	-
Stroke	Wendel-Vos (29)	OPA	9	0.74 (0.49-1.12)		-
	2004	LTPA	19	0.78 (0.71-0.85)		
Lymphoma	Vermaete (42)	OPA	5	0.98 (0.80-1.21)		-
	2013	LTPA	8	0.86 (0.73-1.02)		+
Oesophageal	Behrens (47)	OPA	6	0.91 (0.46-1.80)		-
	2014	LTPA	10	0.72 (0.63-0.83)	·	
Pancreatic cancer	O'Rorke (53)	OPA	3	0.75 (0.59-0.96)		-
	2010	LTPA	16	0.94 (0.88-1.01)		+
T2D	Aune (56)	OPA	3	0.85 (0.79-0.92)*		-
	2015	LTPA	56	0.74 (0.70-0.79)*	- + ·	
Hypertension	Huai (62)	OPA	6	0.93 (0.81-1.07)	-	-
	2011	LTPA	12	0.81 (0.77-0.86)	- Lu - 1 - 1 -	1 T

Figure 3 Forest plot depicting the evidence for the association of physical activity and health. Association for occupational and leisure-time physical activity are depicted. *Effect of LTPA and OPA is statistically significantly different ($p \le 0.05$). An arrow indicates effect sizes that were out of range of our figure. CHD, coronary heart disease; LTPA, leisure-time physical activity; OPA, occupational physical activity; T2D, diabetes mellitus type 2.



Figure 4 Dose–response associations for occupational physical activity and health. MET, metabolic equivalent of task; OPA, occupational physical activity.

category was found to have the highest reduced risk.²⁹ The results also showed that there was no evidence for an association between high-level or moderate-level OPA and hypertension.⁶² Mahmood reported the pooled RR for colon cancer with an OPA level per 210 metabolic equivalent of task (MET) hour/ week (RR 0.86, 95% CI 0.80 to 0.91). This effect was stronger for men (RR 0.82, 95% CI 0.76 to 0.88) than for women (RR 0.96, 95% CI 0.86 to 1.08). In the same review, the pooled RR with OPA level per 210 MET our/week for rectal cancer was (RR 0.94, 95% CI 0.87 to 1.01).³³

DISCUSSION Main findings

In this umbrella review, we summarised the evidence on the associations between OPA and 23 health-related outcomes based on 17 systematic reviews that included 158 individual studies. Engaging in high versus low OPA showed beneficial health effects for multiple cancer outcomes, stroke, CHD and mental health. In contrast, high versus low OPA showed unfavourable health outcomes regarding all-cause mortality in men, mental ill health, osteoarthritis and sleep duration and/or quality. For some outcomes, our results are inconclusive (ie, for several cancer outcomes, hypertension, all-cause mortality in females). We identified no reviews on adiposity, cognitive outcomes or health-related quality of life. The associations between OPA and health-related outcomes, for most outcomes, were not differential from that of LTPA in direction and/or magnitude. Although for three health outcomes we found a significant difference in magnitude (figure 3), LTPA showed a higher protective effect in distal colon cancer, CHD and diabetes type 2 than OPA. Reviews that reported unfavourable health outcomes for OPA (ie, allcause mortality in men, osteoarthritis and sleep duration and/ or sleep quality) did not report on LTPA, as a result of which we could not make a comparison between OPA and LTPA.

Only three reviews, addressing five outcomes, reported doseresponse associations of OPA and health. We can, therefore, only make limited inferences on the health effects of the full OPA continuum. Higher OPA-specific energy expenditure was associated with a gradually reduced risk of colon cancer and to a lesser extent a reduced risk for rectal cancer. For hypertension and ischaemic stroke, the highest OPA groups were associated with the lowest risk (although non-significant for hypertension).

Interpretation of the results

In this umbrella review, we applied the GRADE method. Other criteria to evaluate the quality of evidence have been proposed in other reviews¹³⁻¹⁵ and by other organisations.⁶³ Using such criteria could have possibly led to other results in the interpretation of the reviews identified in our umbrella review. None of

the relationships we identified were supported by strong evidence (with moderate GRADE scores at best) and therefore results should be interpreted with caution. We only detected evidence from systematic reviews of observational studies, which bears a higher risk of selection bias and confounding.⁶⁴ All identified evidence suffers from risk of bias (eg, misclassification, publication bias and confounding bias) and reviews showed high heterogeneity and/or inconsistent results. Studies varied widely regarding the confounding variables that were considered and relevant variables such as socioeconomic status, body mass index and lifestyle factors (eg, smoking, alcohol and diet) were not addressed in every study. All reviews reported issues with the measurements of PA, specifically with the use of self-reported methods to assess OPA in all reviews and studies. Measuring OPA can be challenging as the occupational dose and intensity can fluctuate over time (eg, between days, weeks or seasons) and a general shift in OPA from physically demanding jobs to more sedentary occupations has been seen over the last decades.⁶⁵ As most studies of the current evidence base assessed OPA only at a single instance, changes over time were not considered, which could have led to misclassification. On the other hand, OPA could be less subjected to recall bias than LTPA because of the routine nature of OPA and relatively long (ie, sometimes livelong) exposure to OPA.⁶⁶ Self-reported PA may suffer from several biases^{67 68} induced by socially desirable or culturally influenced answers; for example, variation across socioeconomic and demographic groups,⁶⁹ participants' inability to assess PA at different intensities and recall bias.⁷⁰ Arbitrary cut-off points (with heterogeneous definitions) to operationalise OPA categories were used and precision was reduced by using dichotomous OPA categories.

Most reviews were able to include a substantial number of studies on LTPA since reviews often had their main focus on either LTPA or total PA (ie, OPA and LTPA combined). Only limited evidence was available for OPA, sometimes from subgroup analyses only. In addition, reviews could or did not detect heterogeneity/publication bias for OPA. Some reviews did not draw any conclusions on OPA or stated that more evidence was needed on this topic. In contrast, reviews with a relatively high number of included studies on OPA showed the importance of subgroup analyses to provide more profound insight. The review about prostate cancer showed, for example, that higher quality studies had a lower reduced risk in comparison with lower quality studies; cohort studies showed a lower reduced risk in comparison with case-control studies.⁵² In this review, a statistically significant beneficial health effect of OPA was only evident in studies with a long follow-up (median >10 years).⁵² Coenen et al showed that high OPA was related to an increased risk of all-cause mortality for men, but a non-significant decreased risk for women.²⁸

Sensitivity analyses were used to assess the consistency of the evidence when multiple reviews were available per health outcome. These analyses showed that almost all reviews provided comparable direction and magnitude of effect sizes. The two reviews on all-cause mortality, however, showed opposite effects. Coenen et al reported that the risk of all-cause mortality was higher for male workers,²⁸ while Samitz et al reported in an earlier review with fewer studies that men with higher OPA had a reduced risk of all-cause mortality.²⁷ While both reviews had a low GRADE-score, we synthesised the findings from the most recent review, which also included more studies.²⁸ The evidence was therefore considered to be more up to date. Nevertheless, while in the male population high level OPA was associated with all-cause mortality, other included reviews on the leading causes of death,⁷¹ such as CVD and cancer outcomes, showed favourable health outcomes for high versus low OPA. The aforementioned and other methodological issues could partly explain these contradictory findings.^{9 10} There are also several plausible physiological explanations as to why OPA might not confer the cardiovascular health benefits of LTPA.8 For example, LTPA entails dynamic movements which is mostly performed voluntarily over short time periods with sufficient recovery time, while OPA is most often of too low intensity or of too long duration to be health beneficial.

Methodological strengths and limitations

We followed a systematic methodology including search strategy in electronic databases and independent study selection and extraction by two researchers. We also used standard approaches to assess the quality of methods (AMSTAR2) and to rate the quality of the evidence (GRADE). GRADE has increasingly been adopted by organisations worldwide for grading evidence and for guideline development.²⁰ Moreover, if a review did not report on heterogeneity (in terms of I² statistics) or publication bias (eg, using funnel plots), we reanalysed the available data, leading to more accurate GRADE scores.

A limitation of our umbrella review is that with the rapidly evolving body of evidence on the health effects of OPA, evidence may have only recently been published and as a consequence has not been summarised in reviews yet. For example, since the review by Coenen *et al* (with literature search until September 2017) at least six new studies reporting on all-cause mortality and OPA would have met the inclusion criteria for systematic reviews included in our umbrella review.¹⁰ None of the systematic reviews included experimental studies, although some individual experimental studies addressed the relationship between OPA and health-related outcomes.⁷² ⁷³ Experimental studies provide more insight into causality and deal with issues such as selection bias and confounding.

We included reviews that addressed OPA with at least an aerobic component and excluded reviews with only biomechanical (eg, lifting, kneeling) OPA components. We only included health-related outcomes prioritised by WHO (online supplemental material table 2); thereby excluding evidence on outcomes such as musculoskeletal and neurological disorders. The limitation of the exclusion of neurological outcomes seems to have hardly any influence on our findings. For example, Morgan *et al* could not provide any convincing evidence on the associations between OPA and dementia in later life.⁷⁴ Stephen *et al* showed that there was inconclusive evidence regarding the associations between OPA and Alzheimer's disease.⁷⁵ However, it is known that high biomechanical demands at work, such as lifting and heavy manual work, are associated with increased risk of musculoskeletal disorders such as low back, neck/shoulder and lower extremity pain.^{76–78} We also reported on outcomes that are closely related (eg, colon cancer and rectal cancer) because they were addressed in separate systematic reviews.^{33 34 36}

Implications for future research

WHO guidelines on PA and sedentary behaviour (2020) state that more evidence is needed on the health effects of occupational OPA.⁷⁹ We recommend that further research addressing OPA should be based on more sophisticated OPA assessments (eg, using a combination of device measured PA and a diary to distinguish domains of PA). This will help to address biases due to self-reports and can additionally measure PA metrics, such as intensity, duration and frequency.¹⁰ Second, we recommend that reviews and prospective cohort studies examine health effects by PA domains, so that possible differential health effects of LTPA and OPA can further be explored. Third, to get a better understanding of the health-related outcomes of OPA, it is important to consider biomechanical demands at work and musculoskeletal disorders. Particularly since musculoskeletal disorders, such as (low) back and neck pain, result in considerable healthcare spending,⁸⁰ as well as substantial indirect cost due to presenteeism and absenteeism,⁸¹ and are among the leading causes of disability worldwide.^{82 83} To increase the quality of evidence, more experimental studies comparing OPA with health-related outcomes should be conducted and included in systematic reviews. Lastly, we urge researchers to conduct subgroup analyses, if possible (such as for gender), since these seem to provide a more thorough understanding of the health effects of OPA.

Implications for practice

High-quality evidence on the relationship between LTPA and the prevention of non-communicable diseases is available and has been incorporated in national and global guidelines.³ WHO guidelines advise that some PA is better than none and recommend working age adults to engage in at least 150–300 min of moderate-intensity PA per week. The recommended amounts of PA can be done as part of leisure, transportation, work and household activities.⁷⁹

There is inconclusive evidence of very low to moderate quality for OPA to provide comparable beneficial health effects to LTPA. At this point, there is a need for better quality evidence to provide a unequivocal statement on the health effects of OPA.

As the evidence base develops, a more nuanced message concerning the health effects of OPA may be possible. Such a nuanced message will be relevant to large parts of the working population, in particular, those from low socioeconomic groups and people in low-income and middle-income countries who do most of their daily PA at work.^{84 85} Although more high-quality evidence is still needed on health effects of OPA, OPA holds many workers back from engaging in sufficient LTPA due to fatigue and exertion from work, and therefore, it may limit the beneficial health effects of engaging in LTPA for a large fraction of the adult population.⁸⁶

CONCLUSION

We found that high OPA has favourable health associations with most health-related outcomes (multiple cancer outcomes, stroke, CHD and mental health). Other reviews showed unfavourable health associations with high OPA levels (all-cause mortality in men, mental ill health, osteoarthritis and poor sleep duration and/or quality).

Review

Included reviews were of very low to moderate quality. To increase the quality, future research should focus on sophisticated PA measurements, include relevant confounders such as socioeconomic status, lifestyle factors and other types of PA and regular updating of existing systematic reviews. Improved research will lead to a better understanding of the associations between OPA and health-related outcomes.

What is already known

- Adequate physical activity (PA) prevents a range of lifestylerelated, non-communicable diseases.
- It is uncertain if all domains of PA have comparable health effects, with some evidence suggesting that leisure time PA (LTPA) and occupational PA (OPA) may have differential health effects.
- Methodological issues or differences posture, intensity level, frequency, duration and/or recovery time between OPA and LTPA could explain these differential health effects of different PA domains.

What are the new findings

- This umbrella review, which is the first of its kind, suggests that high occupational physical activity (OPA) was beneficial for most health outcomes including coronary heart disease and several cancers.
- High OPA showed unfavourable associations with all-cause mortality in men, mental ill health, osteoarthritis and sleep duration and/or quality.
- This review synthesised a heterogeneous evidence base of very low to moderate quality, highlighting the need for better quality research in this area.

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REFERENCES

- U.S. Department of Health and Human Services. *Physical activity guidelines for Americans. in: services DoHaH, editor. physical activity guidelines for Americans 2018.* Washington, DC, 2018.
- 2 Organization WH. *Global recommendations on physical activity for health*. Geneva: World Health Organization, 2010.
- 3 World Health Organiszation. *Global action plan for the prevention and control of noncommunicable diseases 2013-2020.* WHO, editor. Geneva, 2013.
- 4 Bull F A-AS, Biddle S, Borodulin K, et al. Guidelines on physical activity and sedentary behaviour. Br J Sports Med. In Press 2020.
- 5 Clays E, Lidegaard M, De Bacquer D, et al. The combined relationship of occupational and leisure-time physical activity with all-cause mortality among men, accounting for physical fitness. Am J Epidemiol 2014;179:559–66.
- 6 Harari G, Green MS, Zelber-Sagi S. Combined association of occupational and leisure-time physical activity with all-cause and coronary heart disease mortality among a cohort of men followed-up for 22 years. *Occup Environ Med* 2015;72:617–24.
- 7 Richard A, Martin B, Wanner M, *et al.* Effects of leisure-time and occupational physical activity on total mortality risk in NHANES III according to sex, ethnicity, central obesity, and age. *J Phys Act Health* 2015;12:184–92.
- 8 Holtermann A, Krause N, van der Beek AJ, et al. The physical activity paradox: six reasons why occupational physical activity (opa) does not confer the cardiovascular health benefits that leisure time physical activity does. Br J Sports Med 2018;52:149–50.
- 9 Shephard RJ. Is there a 'recent occupational paradox' where highly active physically active workers die early? Or are there failures in some study methods? *Br J Sports Med* 2019;53:1557–9.
- 10 Coenen P, Huysmans MA, Holtermann A, et al. Towards a better understanding of the 'physical activity paradox': the need for a research agenda. Br J Sports Med 2020;54:1055–7.
- 11 Bastian H, Glasziou P, Chalmers I. Seventy-Five trials and eleven systematic reviews a day: how will we ever keep up? *PLoS Med* 2010;7:e1000326.
- 12 Aromataris E, Fernandez R, Godfrey CM, et al. Summarizing systematic reviews: methodological development, conduct and reporting of an umbrella review approach. Int J Evid Based Healthc 2015;13:132–40.
- 13 Rezende LFMde, Sá THde, Markozannes G, et al. Physical activity and cancer: an umbrella review of the literature including 22 major anatomical sites and 770 000 cancer cases. Br J Sports Med 2018;52:826–33.
- 14 Erickson KI, Hillman C, Stillman CM, et al. Physical activity, cognition, and brain outcomes: a review of the 2018 physical activity guidelines. *Med Sci Sports Exerc* 2019;51:1242–51.
- 15 Dipietro L, Evenson KR, Bloodgood B, *et al*. Benefits of physical activity during pregnancy and postpartum: an umbrella review. *Med Sci Sports Exerc* 2019;51:1292–302.
- 16 PROSPERO. PROSPERO registration; the evidence on the associaton between occupational physical activity and healh; an umbrella review, 2020. Available: https:// www.crd.york.ac.uk/prospero/display_record.php?RecordID=163090
- Ouzzani M, Hammady H, Fedorowicz Z, Mourad Ouzzani H, et al. Rayyan—a web and mobile APP for systematic reviews. Syst Rev 2016;5.
- 18 Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ 2017;358:j4008.
- 19 Shea BJ, Hamel C, Wells GA, *et al*. AMSTAR is a reliable and valid measurement tool to assess the methodological quality of systematic reviews. *J Clin Epidemiol* 2009;62:1013–20.
- 20 Guyatt GH, Oxman AD, Vist GE, et al. Grade: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 2008;336:924–6.
- 21 Huguet A, Hayden JA, Stinson J, *et al*. Judging the quality of evidence in reviews of prognostic factor research: adapting the grade framework. *Syst Rev* 2013;2:71.
- 22 van der Molen HF, Foresti C, Daams JG, et al. Work-Related risk factors for specific shoulder disorders: a systematic review and meta-analysis. Occup Environ Med 2017;74:745–55.
- 23 Guyatt GH, Oxman AD, Kunz R, et al. What is "quality of evidence" and why is it important to clinicians? BMJ 2008;336:995–8.
- 24 Higgins JPT, Thompson SG, Deeks JJ, *et al*. Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557–60.
- 25 Sterne JAC, Sutton AJ, Ioannidis JPA, et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. BMJ 2011;343:d4002.
- 26 Altman DG, Bland JM. Interaction revisited: the difference between two estimates. BMJ 2003;326:219.
- 27 Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality. systematic review and dose-response meta-analysis of cohort studies. *Gynakologische Praxis* 2012;36:137–43.

- Review
- Br J Sports Med: first published as 10.1136/bjsports-2020-102587 on 25 November 2020. Downloaded from http://bjsm.bmj.com/ on April 27, 2024 by guest. Protected by copyright

- 28 Coenen P, Huysmans MA, Holtermann A, et al. Do highly physically active workers die early? A systematic review with meta-analysis of data from 193 696 participants. Br J Sports Med 2018;52:1320–6.
- 29 Wendel-Vos GCW, Schuit AJ, Feskens EJM, et al. Physical activity and stroke. A metaanalysis of observational data. Int J Epidemiol 2004;33:787–98.
- 30 Li J, Loerbroks A, Angerer P. Physical activity and risk of cardiovascular disease: what does the new epidemiological evidence show? *Curr Opin Cardiol* 2013;28:575–83.
- 31 Sattelmair J, Pertman J, Ding EL, et al. Dose response between physical activity and risk of coronary heart disease: a meta-analysis. *Circulation* 2011;124:789–95.
- 32 Wolin KY, Yan Y, Colditz GA, et al. Physical activity and colon cancer prevention: a meta-analysis. Br J Cancer 2009;100:611–6.
- 33 Mahmood S, MacInnis RJ, English DR, et al. Domain-Specific physical activity and sedentary behaviour in relation to colon and rectal cancer risk: a systematic review and meta-analysis. Int J Epidemiol 2017;46:1797–813.
- 34 Boyle T, Keegel T, Bull F, et al. Physical activity and risks of proximal and distal colon cancers: a systematic review and meta-analysis. J Natl Cancer Inst 2012;104:S332–3.
- 35 Samad AKA, Taylor RS, Marshall T, et al. A meta-analysis of the association of physical activity with reduced risk of colorectal cancer. Colorectal Dis 2005;7:204–13.
- 36 Robsahm TE, Aagnes B, Hjartåker A, et al. Body mass index, physical activity, and colorectal cancer by anatomical subsites: a systematic review and meta-analysis of cohort studies. *Eur J Cancer Prev* 2013;22:492–505.
- 37 Wu Y, Zhang D, Kang S. Physical activity and risk of breast cancer: a meta-analysis of prospective studies. *Breast Cancer Res Treat* 2013;137:869–82.
- 38 Pizot C, Boniol M, Mullie P, et al. Physical activity, hormone replacement therapy and breast cancer risk: a meta-analysis of prospective studies. Eur J Cancer 2016;52:138–54.
- 39 Chen X, Wang Q, Zhang Y, et al. Physical activity and risk of breast cancer: a metaanalysis of 38 cohort studies in 45 study reports. Value Health 2019;22:104–28.
- 40 Voskuil DW, Monninkhof EM, Elias SG, et al. Physical activity and endometrial cancer risk, a systematic review of current evidence. Cancer Epidemiol Biomarkers Prev 2007;16:639–48.
- 41 Schmid D, Behrens G, Keimling M, et al. A systematic review and meta-analysis of physical activity and endometrial cancer risk. Eur J Epidemiol 2015;30:397–412.
- 42 Vermaete NVH, Wolter P, Verhoef GEG, et al. Physical activity and risk of lymphoma: a meta-analysis. Cancer Epidemiol Biomarkers Prev 2013;22:1173–84.
- 43 Singh S, Devanna S, Edakkanambeth Varayil J, *et al*. Physical activity is associated with reduced risk of esophageal cancer, particularly esophageal adenocarcinoma: a systematic review and meta-analysis. *BMC Gastroenterol* 2014;14:101.
- 44 Psaltopoulou T, Ntanasis-Stathopoulos I, Tzanninis I-G, *et al*. Physical activity and gastric cancer risk: a systematic review and meta-analysis. *Clin J Sport Med* 2016;26:445–64.
- 45 Chen Y, Yu C, Li Y. Physical activity and risks of esophageal and gastric cancers: a meta-analysis. *PLoS One* 2014;9:e88082.
- 46 Behrens G, Jochem C, Keimling M, et al. The association between physical activity and gastroesophageal cancer: systematic review and meta-analysis. Eur J Epidemiol 2014;29:151–70.
- 47 Behrens G, Leitzmann MF. The association between physical activity and renal cancer: systematic review and meta-analysis. Br J Cancer 2013;108:798–811.
- 48 Shephard RJ. Can habitual physical activity contribute to reducing the health burden of renal cancer? IJASS 2016;28:148–63.
- 49 Krstev S, Knutsson A. Occupational risk factors for prostate cancer: a meta-analysis. J Cancer Prev 2019;24:91–111.
- 50 Benke IN, Leitzmann MF, Behrens G, et al. Physical activity in relation to risk of prostate cancer: a systematic review and meta-analysis. Ann Oncol 2018;29:1154–79.
- 51 Shephard RJ. Physical activity and prostate cancer: an updated review. Sports Med 2017;47:1055–73.
- 52 Liu Y, Hu F, Li D, *et al*. Does physical activity reduce the risk of prostate cancer? A systematic review and meta-analysis. *Eur Urol* 2011;60:1029–44.
- 53 O'Rorke MA, Cantwell MM, Cardwell CR, et al. Can physical activity modulate pancreatic cancer risk? A systematic review and meta-analysis. Int J Cancer 2010;126:NA–68.
- 54 Bao Y, Michaud DS. Physical activity and pancreatic cancer risk: a systematic review. *Cancer Epidemiol Biomarkers Prev* 2008;17:2671–82.
- 55 Keimling M, Behrens G, Schmid D, *et al*. The association between physical activity and bladder cancer: systematic review and meta-analysis. *Br J Cancer* 2014;110:1862–70.
- 56 Aune D, Norat T, Leitzmann M, *et al*. Physical activity and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis. *Eur J Epidemiol* 2015;30:529–42.
- 57 McWilliams DF, Leeb BF, Muthuri SG, et al. Occupational risk factors for osteoarthritis of the knee: a meta-analysis. Osteoarthritis Cartilage 2011;19:829–39.
- 58 Gignac MAM, Irvin E, Cullen K, et al. Men and women's occupational activities and the risk of developing osteoarthritis of the knee, hip, or hands: a systematic review and recommendations for future research. Arthritis Care Res 2020;72:378–96.

- 59 Palmer KT. Occupational activities and osteoarthritis of the knee. Br Med Bull 2012;102:147–70.
- 60 White RL, Babic MJ, Parker PD, et al. Domain-Specific physical activity and mental health: a meta-analysis. Am J Prev Med 2017;52:653–66.
- 61 Yang B, Wang Y, Cui F, et al. Association between insomnia and job stress: a metaanalysis. Sleep Breath 2018;22:1221–31.
- 62 Huai P, Xun H, Reilly KH, et al. Physical activity and risk of hypertension: a metaanalysis of prospective cohort studies. *Hypertension* 2013;62:1021–6.
- 63 WCRFAIfC R. Food, nutrition, physical activity, and the prevention of cancer:a global perspective. Washington, DC: American Institute for Cancer Research, 2007.
- 64 Renjith V. Blinding in randomized controlled trials: what researchers need to know? Manipal J Nurs Health Sci 2017;3:45–50.
- 65 Church TS, Thomas DM, Tudor-Locke C, *et al*. Trends over 5 decades in U.S. occupationrelated physical activity and their associations with obesity. *PLoS One* 2011;6:e19657.
- 66 Mantel N. Avoidance of bias in cohort studies. *Natl Cancer Inst Monogr* 1985;67:169–72.
- 67 Prince SA, Adamo KB, Hamel ME, et al. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. Int J Behav Nutr Phys Act 2008;5:56.
- 68 Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. Br J Sports Med 2003;37:197–206.
- 69 Kapteyn A, Banks J, Hamer M, et al. What they say and what they do: comparing physical activity across the USA, England and the Netherlands. J Epidemiol Community Health 2018;72:471–6.
- 70 Skender S, Ose J, Chang-Claude J, et al. Accelerometry and physical activity questionnaires - a systematic review. BMC Public Health 2016;16:515.
- 71 Hannah Ritchie MR. Causes of death, 2020. Available: https://ourworldindataorg/ causes-of-death
- 72 Korshøj M, Krause N, Clays E, et al. Does aerobic exercise increase 24-hour ambulatory blood pressure among workers with high occupational physical activity?—a RCT. Am J Hypertens 2017;30:444–50.
- 73 Korshøj M, Ravn MH, Holtermann A, et al. Aerobic exercise reduces biomarkers related to cardiovascular risk among cleaners: effects of a worksite intervention RCT. Int Arch Occup Environ Health 2016;89:239–49.
- 74 Morgan GS, Gallacher J, Bayer A, et al. Physical activity in middle-age and dementia in later life: findings from a prospective cohort of men in Caerphilly, South Wales and a meta-analysis. J Alzheimers Dis 2012;31:569–80.
- 75 Stephen R, Hongisto K, Solomon A, et al. Physical activity and Alzheimer's disease: a systematic review. J Gerontol A Biol Sci Med Sci 2017;72:733–9.
- 76 Coenen P, Gouttebarge V, van der Burght ASAM, et al. The effect of lifting during work on low back pain: a health impact assessment based on a meta-analysis. Occup Environ Med 2014;71:871–7.
- 77 Lötters F, Burdorf A, Kuiper J, et al. Model for the work-relatedness of low-back pain. Scand J Work Environ Health 2003;29:431–40.
- 78 Coenen P, Willenberg L, Parry S, et al. Associations of occupational standing with musculoskeletal symptoms: a systematic review with meta-analysis. Br J Sports Med 2018;52:176–83.
- 79 World Health Organization. Public consultation on the draft WHO guidelines on physical activity and sedentary behaviour for children and adolescents adults and older adults, 2020. Available: https://www.who.int/news-room/articles-detail/ public-consultation-on-the-draft-who-guidelines-on-physical-activity-andsedentary-behaviour-for-children-and-adolescents-adults-and-older-adults-20202020
- 80 Dieleman JL, Cao J, Chapin A, *et al*. Us health care spending by payer and health condition, 1996-2016. *JAMA* 2020;323:863–84.
- 81 Lambeek LC, van Tulder MW, Swinkels ICS, et al. The trend in total cost of back pain in the Netherlands in the period 2002 to 2007. Spine 2011;36:1050–8.
- 82 Global Burden of Disease Study 2013 Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990-2013: a systematic analysis for the global burden of disease study 2013. *Lancet* 2015;386:743–800.
- 83 Clark S, Horton R. Low back pain: a major global challenge. *Lancet* 2018;391:2302.
- 84 Beenackers MA, Kamphuis CBM, Giskes K, et al. Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults: a systematic review. Int J Behav Nutr Phys Act 2012;9:116.
- 85 Guthold R, Stevens GA, Riley LM, *et al*. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1-9 million participants. *Lancet Glob Health* 2018;6:e1077–86.
- 86 Rasmussen CL, Palarea-Albaladejo J, Bauman A, et al. Does physically Demanding work hinder a physically active lifestyle in low socioeconomic workers? A compositional data analysis based on Accelerometer data. Int J Environ Res Public Health 2018;15:1306.