Public Health England

Protecting and improving the nation's health

Cycling and walking for individual and population health benefits

A rapid evidence review for health and care system decision-makers

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Executive summary

Regular physical activity benefits long-term health, including mental health, and helps to prevent over 20 common health conditions. The UK Chief Medical Officers' guidance for adults includes 150 minutes of moderate intensity activity a week, and that the easiest way to achieve this is through daily activity such as walking and cycling.

Over 4 in 10 women (42%) and 1 in 3 men (34%) in England are not active enough for good health, with human and economic costs for the individual, communities and the health and social care system. The most recent estimates are that physical inactivity costs the NHS more than £450 million a year at Clinical Commissioning Group level, equating to £817,274 per 100,000 individuals or £8.17 per person.

This rapid evidence review is intended for health and social care policy makers, decision makers and commissioners and attempts to address the following question:

"What is the impact of walking and/or cycling on different health outcomes?"

This review found that walking and cycling benefit health in a number of ways:

- people who walk or cycle have improved metabolic health and a reduced risk of premature mortality
- walking and cycling reduce the risk factors for a number of diseases, including cardiovascular disease, respiratory disease, some cancers, and Type II diabetes
- walking and cycling also have positive effects on mental health and general well-being. The mental health and neurological benefits include reduced risk of dementia, improved sleep quality, and a greater sense of wellbeing
- in environmental terms, health benefits accrue for the general population from a reduction in pollution due to car use and a decrease in road congestion
- the evidence is that the health benefits of walking and cycling outweigh any potential health risks and harms – for example from injury or pollution

The weight of evidence suggests that if walking and cycling can be increased, they have potential to lead to important health gains at the population level, and thus benefit the NHS and the wider health and care system.

The evidence is stronger and more consistent for certain health outcomes, and evidence gaps remain in some areas. There is little direct evidence about whether walking or cycling to work might have different health effects to walking or cycling for leisure.

There is little specific evidence available on the benefits of walking and cycling for people with disabilities and those living with long-term conditions. Similarly, there is little about the effects on groups living with different levels of deprivation. It would be helpful if these gaps were addressed, particularly regarding practical methods to improve access to physical activity for these groups.

1. Introduction

The population health benefits of physical activity are well established in the scientific literature [1, 2]. Population recommendations for physical activity are set by the Chief Medical Officer. The Chief Medical Officer's guidance for adults is for 150 minutes of moderate activity a week (2 ½ hours), or for 75 minutes of vigorous activity. The guidance also recommends activities that strengthen muscles, and says that sitting time should be minimised (see Appendix 1 for more details) [2].

The most recent estimates are that lack of physical activity (physical inactivity) costs the NHS more than £450 million a year at Clinical Commissioning Group level. One in 4 women and 1 in 5 men in England are are damaging their health through a lack of physical activity. They are classed as physically inactive – that is, having less than 30 minutes a day of moderate activity.

Walking and cycling have attracted attention as options for increasing population activity levels because they can be fitted around daily life. Walking is one of the main contributors to total physical activity across all age groups in the population and is already the most common activity for older people as shown by data from the Health Survey for England [3, 4]. Cycling for transport can be a time-efficient option for physical activity, as it can be integrated into daily routines.

The World Health Organisation (WHO) includes walking and cycling as key actions in its *Global Action Plan on Physical Activity 2018-2030* [5]. It stated that "investing in policies to promote walking and cycling…can contribute directly to achieving many of the 2030 Sustainable Development Goals (SDGs)".

Promoting walking and cycling has been identified as one of the "Seven Best Investments" to increase population levels of physical activity [6] in the *Toronto Charter for Physical Activity: A Global Call to Action*. This report stated that if walking and cycling promotion was applied at sufficient scale it would "make a significant contribution to reducing the burden of non-communicable diseases and promote population health" and contribute to "improving the quality of life and the environments in which we live".

The Government has set an aim to double cycling activity to 1.6 billion trips per year. This is to aid population health and wellbeing as well as to improve road congestion, air quality, and economic and local development. This ambition is to be realised through the statutory Cycling and Walking Investment Strategy (CWIS). A fuller understanding of the health impacts of increasing walking and cycling will help underpin this investment.

In 2018, Government ministers asked for a clearer summary of the population health benefits and impacts that are specific to walking and cycling. This was to strengthen the national narrative on the benefits of walking and cycling, and to make the health impact case more accessible to local and national system partners. This review has been produced in response.

2. Aims and objectives

This evidence review aims to identify, summarise, and report relevant evidence to support engagement in the Cycling and Walking Investment Strategy (CWIS) [7]. The review attempts to address the following question:

“What is the impact of walking and/or cycling on different health outcomes?”

The objective was to examine the benefits of walking and cycling to individual and population health, and therefore the benefits for local health and social care systems. The intention was to summarise the evidence in one place, in order to support CWIS implementation by the health sector.

3. Methods

The approach for preparing this evidence review is summarised below.

Design

Rapid evidence review

Search strategy

Targeted searching of relevant databases (Medline, Google Scholar, etc.) was conducted. Selected search terms for walking and cycling were used (see Appendix 2), and identified records were screened for relevance to the primary research question/aim.

Scope

Walking and cycling are behaviours that are performed in more than one domain. The scope for this report was walking or cycling for:

- transport, active travel and commuting
- leisure and recreation
- sport, exercise and fitness
- occupation

Table 1 Definitions of walking and cycling

Walking	Walking refers to all forms of purposeful or incidental bipedal locomotion within reasonable speed ranges (ie not running or jogging) [8].
Cycling	Cycling includes bike rides of any length or intensity and covers cycling for different purposes (ie both transport and leisure) [9].

Walking and cycling as part of elite performance and high-level competition were not included.

Evidence from any country was considered for inclusion. Studies were included if there were good epidemiological reasons to assume the evidence would be applicable to the English population. Evidence for all ages was considered for inclusion.

Study selection and reporting the evidence

A hierarchical strategy was used for study selection, first selecting systematic reviews and meta-analyses. When these were not available, scoping and narrative reviews were selected. Finally, high quality individual studies were included. Prospective and experimental study designs were included. Cross-sectional evidence was not reported for aetiological associations, due to known limitations and possible reverse causation (a person with low cardiorespiratory fitness may walk or cycle less due to their health status, rather than low levels of walking or cycling leading to their health status). If included reviews had reported cross-sectional evidence as part of their findings, this evidence would be eligible for reporting here. Cross-sectional evidence has been reported on questions of prevalence. The flow of studies for the primary aim (as reported in section 5) is shown in Appendix 3: Study Flow Chart.

Where available, data were extracted on volume, type or intensity of walking and cycling, and magnitude of effect on health outcomes. For reviews, number and nature/design of studies were extracted, along with any reporting of study quality or bias. For individual studies details including design, population and sample size were extracted.

The analytical framework for the primary research objective was to report:

- the physical health benefits of walking
- the mental health benefits of walking
- the physical health benefits of cycling
- the mental health benefits of cycling

The evidence on these areas is reported in Section 5. The selection of health outcomes was informed by the existing reviews for physical activity and health. The nature of the evidence for each health outcome was assessed according to the following hierarchy:

1. Systematic review and meta-analysis level evidence
2. Scoping and narrative review level evidence
3. Consistent study level evidence
4. Inconsistent study level evidence
5. Fragmented or incomplete level evidence
6. No evidence

Once these sections were reported, emergent and relevant sub-questions were highlighted and discussed, though independent search strategies were not employed in these areas. The evidence for these sections is reported in Sections 6-13. In Section 14, the limitations of the current evidence base are presented. Finally, in Section 15 recommendations for policy and practice are made.

4. Benefits of physical activity overall

Walking and cycling as examples of physical activity

The evidence base for walking and cycling and their impacts on health is increasingly clear and convincing. However, the evidence is not complete and is restricted to what researchers have evaluated. This **direct evidence** specifically on walking and cycling sits within an even wider, more comprehensive, and stronger evidence base for the health impacts of physical activity in general (**indirect evidence**). The strongest physical activity evidence – and that with the greatest mass – exists for moderate to vigorous physical activity (MVPA), of which walking and cycling are excellent (perhaps the best) examples.

The eminent epidemiologist Professor Jeremy Morris famously described walking as the "…nearest activity to perfect exercise" [10]

Figure 1 below shows the place of walking and cycling on the spectrum of sedentary to vigorous activities, as assessed in multiples of resting metabolic rate (Metabolic Equivalent of Task or MET). It is important to note that these are just indications of likely intensity ranges; walking is not always moderate intensity and cycling is not always vigorous. For example, brisk walking up a hill carrying a load would be intense activity. Likewise, slow cycling on a good flat surface would likely be moderate for most people [11].

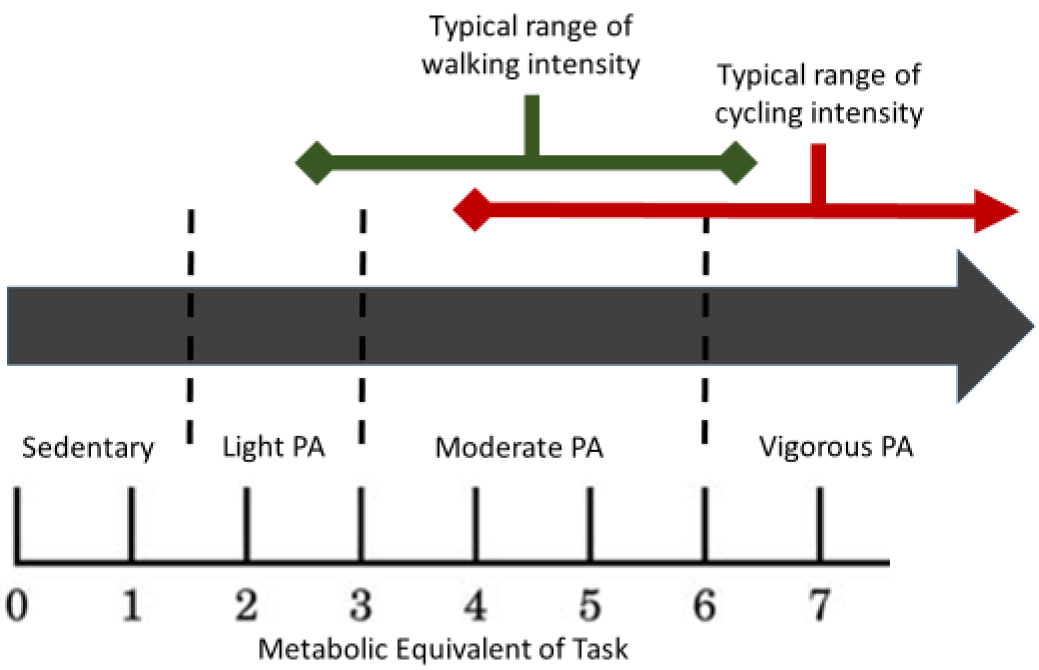

Figure 1. Illustration of walking and cycling as moderate to vigorous physical activities. Note ranges given are indicative and intensity will vary by pace, terrain, fitness, and many other factors. Ranges are estimates, based on the 2011 Compendium of Physical Activities. [11]

The health benefits of physical activity

The Chief Medical Officers have stated that there is strong, consistent and convincing evidence that regular physical activity is beneficial for a wide range of health outcomes and risk factors [2]. This increasingly comes from systematic reviews and meta-analyses of high quality population cohort studies [1]. The health benefits include hard health outcomes such as all-cause mortality, cardiovascular disease, coronary heart disease, and stroke. Regular physical activity reduces the risk for developing many cancers, including those of the breast, colon, bladder, endometrium, oesophagus, kidney, lung, and stomach. It also improves metabolic health reducing the risk of developing Type 2 diabetes, and can help maintain a healthy weight and support weight loss [2]. There are neurological benefits including reduced risk of dementia and mental health outcomes such as reduced depressive symptoms. Moderate-to-vigorous physical activity has been shown to improve the quality of sleep and also quality of life [1].

In summary “regular physical activity can reduce the risk of developing a new chronic condition, reduce the risk of progression of a condition already present, and improve quality of life and physical function” [1]. As exemplars of physical activity, there is therefore very strong **indirect evidence** that walking and cycling can realise these benefits.

How much do walking and cycling contribute to physical activity?

Walking is one of the main contributors to total physical activity across all age groups, contributing between 26-42% of total physical activity [3], and has been demonstrated to be accessible to large proportions of society in terms of age and gender [9]. Cycling is less prevalent, with just 5.7% of people in England cycling 3 or more times per week [11], and 1% of children cycling to school [11]. In comparison, in the Netherlands, men and women achieve an average 24 and 28 minutes respectively of daily physical activity through walking and cycling [12]. Despite the current low prevalence of cycling compared to walking, both have potential to be built into daily routines and may therefore be more likely to be sustained and yield significant increases in weekly physical activity (eg cycling or walking to and from work). The Propensity to Cycle Tool study (2016) estimated that if people in England had the same readiness to cycle a given distance as those in the Netherlands then 18% of people would cycle to work - even allowing for England’s greater hilliness in certain regions [13].

Walking and cycling for travel are likely to have similar health benefits for an individual as other types of physical activity. Due to the higher possibility they can be built into daily life and routine compared to many other physical activities, they have particularly high sustainable population health potential across the life-course.

Dose response relationships between physical activity and health benefits

Physical activities, including walking and cycling can be considered in terms of dose – usually consisting of duration, intensity, and frequency. Dose response meta-analyses and pooled analyses have generally found a non-linear relationship between total dose (volume) of activity and risk of disease, with the greatest benefit in moving from being inactive to doing some level of activity [1]. Magnitude of benefits at higher doses (beyond the WHO higher recommendation of 5 hours per week of moderate activity) are less well established and likely vary by disease outcome.

Duration, intensity, and frequency can be combined to produce total physical activity energy expenditure metrics. This allows us to compare and combine activities of a different kind. A common method for doing this is the Marginal Metabolically Equivalent Task (MMET) rate that represents the body mass adjusted energy expenditure of an activity above the metabolic rate of sedentary behaviour. Typically, walking is moderate and cycling vigorous intensity. However, intensity varies by speed, terrain and hilliness, load carrying, and personal characteristics such as age and fitness (see Figure 1).

Walking and cycling are commonly cited examples of moderate and vigorous activities and are thus likely to have similar benefits to other regular physical activity behaviours of similar intensity conducted for similar durations [1]. Due to the non-linear relationship between volume of activity and disease risk, the marginal benefits of doing more walking and cycling are very likely to depend on the total amount of activity an individual is doing and not just their walking and cycling level. Thus, as with all physical activity, the benefits of increasing walking and cycling are likely to be much higher for those who are inactive.

5. What are the health benefits of walking and cycling specifically?

The following section is a summary of the **direct evidence** for walking and cycling organised in terms of the physical and mental health benefits.

The physical health benefits of walking

In summary, walking is associated with a wide range of physical health benefits for children, adults and older adults [1, 2]. These benefits include reduced risk of all-cause mortality, cardiovascular disease incidence and mortality, coronary heart disease incidence and mortality, certain cancer mortality[1] and type II diabetes incidence. Walking also has beneficial impacts on disease risk markers and musculoskeletal health [1]. The evidence for the physical health benefits of walking is summarised in Table 2 and Table 3 below.

[1] The 2018 US Physical Activity Guidelines Advisory Committee Scientific Report found strong evidence that physical activity reduced risk of a number of cancers including bladder, colon, esophageal adenocarcinoma, renal and gastric and limited evidence for a number more. However, they stated that few data were available on walking specifically and cancer risk, and that this was an important need for future research 1. 2018 Physical Activity Guidelines Advisory Committee, *2018 Physical Activity Guidelines Advisory Committee Scientific Report*. 2018, U.S. Department of Health and Human Services: Washington DC.

Table 2 Review level evidence for effect of walking on disease incidence, disease incidence and mortality, and all-cause mortality

Potential benefits of walking	Findings	Type of evidence for benefits	Quality assessment[2]
All-cause mortality	A systematic review and meta-analysis (search date 2013) of cohort studies (14 studies; 280,000 people) reported an 11% (95% confidence intervals (CI) 4 to 17%) reduced risk of all-cause mortality in those who meet physical activity guidelines through walking (11.25 MET.hours/week) compared to those with no walking [14]. These findings are supported by another systematic review and meta-analysis (search date 2009) of cohort studies (five studies; 217,042 people) which also reported an 11% (95% CI 4 to 18%) reduced risk of all-cause mortality in those who meet physical activity guidelines through walking (11.25 MET.hours/week) compared to those with no walking [15].	Systematic review level (cohort)	From 14 studies, 10 scored 8 or 9/9 (none less than 7) [14]; mean 6/9 [15]
Cardiovascular disease	One systematic review and meta-analysis (search date 2007) of 18 cohort studies (459,833 people) found that high levels of walking reduced cardiovascular disease risk by 31% (95% CI 23 to 39%) compared with low levels of walking [16].	Systematic review level (cohort)	Mean score of 5.3/7
Coronary heart disease	One systematic review (search date 2007) of 11 cohort studies and one RCT (295,177 people) found a dose response relationship for walking and coronary heart disease risk. Walking for 30 minutes/day five days per week was associated with a 19% (95% CI 14 to 23%) reduced risk of coronary heart disease compared with no walking [17].	Systematic review level (cohort and RCT)	No quality assessment reported
Cancer	One systematic review and meta-analysis (search date 2012) of cohort studies (five studies; 304,123 people) reported a 3% (95% CI 2 to 5%) reduction in breast cancer risk for every 10 MET.hours/week of walking [18]. Another systematic review and meta-analysis (search date 2014) of ten studies (four cohort, one case-cohort and three case control studies; 251,693 people) reported an 18% (95% CI 3 to 31%) reduction in risk of endometrial cancer in high versus low levels of walking [19].	Systematic review level (cohort and case-control)	No quality assessment [18]; 20/33 studies scored >6/9 [19]
Type II diabetes	One systematic review (search date 2006) of cohort studies (five studies; 240,605 people) found that walking for 2.5 hours/week at a brisk pace is associated with a 17% (95% CI 9 to 25%) lower risk of developing type II diabetes compared with no walking [20]. Experimental design evidence also reports that walking is protective against progressing to diabetes [21] and improving glucose tolerance [22, 23].	Systematic review level (cohort, crossover and RCTs)	No quality assessment reported

[2] As reported by the review authors in included reviews. Higher scores mean better quality rating eg 0/9 lowest quality; 9/9 highest quality.

Table 3 Review level evidence for the physical health benefits of walking on intermediate risk factors

Potential benefits of walking	**Findings**	**Type of evidence for benefits**	**Quality assessment (systematic reviews only)**
Cardiorespiratory fitness	Review evidence found that walking can improve cardiorespiratory fitness in adults, but the evidence for children is inconclusive. One systematic review and meta-analysis (search date 2012) of RCTs (18 studies; 894 people) found that walking interventions at a moderate intensity had a 3.04mL/kg/min (95% CI 2.48 to 3.60) improvement in cardiorespiratory fitness (approximately 10%) in inactive participants with modest levels of aerobic fitness [24]. Intensity and duration of interventions for each outcome were not separately reported (as the review reported other outcomes) but for the review as a whole interventions were on average 18.7 weeks long (for 20-60 minutes, 2-7 days per week). Another systematic review (search date 2012) of ten studies (eight cross sectional and two prospective; 26,948 children) reported inconclusive evidence that walking to school was associated with improved cardiorespiratory fitness in young people compared with those who travelled to school passively [25]. The average distance travelled/activity time and intensity was not reported.	Systematic review level for adults Inconclusive evidence for children	Only 2/18 studies rated as low risk of bias [24] Predominantly moderate quality, [25]
Blood pressure	Two systematic reviews found that walking can improve blood pressure. One systematic review (search date 2012) of RCTs (16 studies; 816 people) found that walking interventions significantly reduced systolic (-3.58 mm Hg, 95% CI -5.19 to -1.97) and diastolic (-1.54 mm Hg, 95% CI -2.83 to -0.26) resting blood pressure [24]. Intensity and duration of interventions for each outcome were not separately reported (as the review reported other outcomes) but for the review as a whole interventions were on average 18.7 weeks long (for 20-60 minutes, 2-7 days per week). Another systematic review (search date 2007) of RCTs and non-randomised interventions (12 studies; 468 people; number of RCTs and non-randomised interventions in each analysis not reported) found a -3.8 mm Hg reduction (95% CI -1.7 to -5.9) in systolic blood pressure and a -0.3 mm Hg (95% CI 0.02 to -0.46) reduction in diastolic blood pressure as a result of increased walking (average increase of 2491 and 2183 steps/day in the RCTs and the non-randomised interventions respectively) [26].	Systematic review level (RCTs & non-randomised interventions)	Only 2/18 studies rated as low risk of bias [24] No quality assessment [26]
Vascular function	Review evidence has found that studies predominantly focus on the role of general exercise training on vascular function, with exercise training leading to improvements [27], however preliminary evidence from a RCT (77 people) suggests that walking for 30 minutes at a brisk intensity five days per week can beneficially improve arterial stiffness [28].	Fragmented or incomplete level evidence (RCT)	N/A
Blood lipids	Mixed evidence for the role of walking on blood lipids was identified. One meta-analysis (search date 2012) of RCTs (16 studies; 758 people) found no significant effects of walking on cholesterol [24]. Intensity and duration of interventions for each outcome were not separately reported (as the review reported other outcomes) but for the review as a whole interventions were on average 18.7 weeks long (for 20-60 minutes, 2-7 days per week).	Inconclusive systematic review level (RCTs and observational studies)	Only 2/18 studies rated as low risk of bias [24] No quality assessment [26]

	Another review (search date 2007) of RCTs and observational studies (seven studies; 192 people) also found no significant effects (-0.09 95% CI -0.32 to 0.15) of walking interventions on blood lipids (average increase of 2491 steps/day in the RCTs; observation data not reported) [26]. A third review found that physical activity can reduce postprandial lipemia [29]. Whilst the latter review was not specific to walking, Gill and Hardman [30] suggest that energy expenditure during the activity rather than either the intensity or mode of activity is the most important determinant of lowering lipids.		
Haemostatic, inflammatory and immune function markers	One review (search date 2015, number of participants not reported) included three cross-sectional studies and one crossover trial and found preliminary evidence for improved haemostatic, inflammatory and immune function markers with regular walking [31]. Intervention descriptions/physical activity duration and intensity were not reported.	Narrative review level (cross-sectional & crossover trial)	No quality assessment
Body composition	Three systematic reviews found evidence to suggest that walking can lead to improvements in body composition. One systematic review and meta-analysis (search date 2012) of RCTs (25 studies; 1275 people) found that walking interventions were associated with an average weight loss of -1.37kg (95% CI -1.75 to -1.00) [24]. The same review also found that walking interventions (23 RCTs; 1201 people) led to reductions in BMI of -0.5 kg.m-2 (95% CI -0.72 to -0.35), and -1.51cm (95% CI -2.34 to -0.68) reductions in waist circumference (11 RCTs; 574 participants) [24]. Intensity and duration of interventions for each outcome were not separately reported (as the review reported other outcomes) but the average walking intervention duration for the review as a whole was 18.7 weeks long (for 20-60 minutes, 2-7 days per week). Another systematic review (search date 2007) of RCTs and non-randomised interventions (18 studies; 562 people; number of RCTs and non-randomised interventions in each analysis not reported) found that walking (average increase of 2491 and 2183 steps/day in the RCTs and non-randomised interventions respectively) led to a -0.38 kg.m-2 (95% CI -0.05 to -0.72) reduction in BMI [26]. Finally, a systematic review (search date 2015) of RCTs (22 studies; 1524 people) found that walking (average 46 minutes, moderate intensity for four sessions/week for 12 to 16 weeks) was associated with a -2.13kg (95% CI -3.20 to -1.06) average weight loss, a -0.96 kg.m-2 (95% CI -1.44 to -0.48) reduction in BMI and -2.83 (95% CI -4.13 to -1.53) reduction in waist circumference [32].	Systematic review level (RCTS, interventions & observational)	Only 2/18 studies rated as low risk of bias [24] No quality assessment [26] Predominantly moderate quality [32]
Musculoskeletal health	One non-systematic review (search date 2015) noted there is inconclusive evidence for walking to improve musculoskeletal health in healthy individuals, however the review did not report details of this evidence [31]. The same review identified two further systematic reviews that found evidence that walking interventions can benefit musculoskeletal health in postmenopausal women [33] and adults with chronic back pain [34], suggesting that walking may benefit individuals with impaired musculoskeletal health. A systematic review and meta-analysis (search date 2006) found that walking interventions had significant positive effects at the femoral neck of 0.014g/cm^2 (95% CI 0.000 to 0.028) (four RCTs, one non-randomised trial; 302 people) but not the lumbar spine 0.007g/cm^2 (95% CI -0.001 to 0.016) (four	Systematic review level (for individuals with impaired musculoskelet al health) (RCTs and non-randomised	Average quality score 2/5 [33] 3 low risk, 1 unclear, 3 high risk [34]

	RCTs, one non-randomised trial; 427 people) in postmenopausal women [33]. Interventions were predominantly three sessions/week, ranging from 20-50 minutes per session and 7-24 months duration. Intensity of walking was not reported. The second systematic review (search date 2015) of RCTs (seven studies; 869 people) found that walking is as effective as usual care in people with chronic back pain [34]. Interventions ranged from 4 weeks to 12 months and the volume ranged from 40 minutes twice/week to walking programs that were individually tailored and increased in volume each week. Intensity of walking was not reported.	trials)	

The mental and neurological health benefits of walking

The Physical Activity Guidelines Advisory Committee Scientific Report in the USA in 2018 reviewed multiple health outcomes. It concluded that walking is associated with improved mental and neurological health [1]. Benefits include fewer symptoms of depression and lower incidence of depression (including in post-partum women), reduced risk of dementia, improved cognitive function, improved quality of life (and sleep quality), and reduced feelings of anxiety [1].

The most up to date and comprehensive account of the benefits of walking for mental health is a scoping review published by Kelly et al., in 2018 [8]. The authors pre-specified which mental health outcomes to investigate; depression, anxiety, self-esteem, psychological stress, psychological well-being, subjective well-being, resilience, social isolation and loneliness (see Appendix 4 for definitions). Five systematic reviews and 50 papers were included.

The authors concluded that the evidence base for walking and mental health has grown considerably over the past 2 decades. For depression and anxiety, the evidence shows consistent beneficial effects. For other outcomes, evidence is still “emerging” and at times mixed, often characterised by cross-sectional study designs. The evidence for the benefits of walking on these outcomes is summarised in Table 4 below.

The scoping review by Kelly et al., [8] also found “emerging evidence” that the environmental context of walking plays a role in the mental health benefit. There was consistent evidence to suggest that outdoor and green environments confer mental health benefits beyond those from walking indoors or in the built environment. However, the studies were generally short term or single bout designs with small sample sizes, and so further research is needed in this area. There was limited evidence on the social context of walking (walking alone versus walking with others) as well as the type of walking (commuter, dog walking, leisure walking) and therefore no clear conclusions can be drawn [8].

Table 4 Mental and neurological health outcomes of walking* (adapted from Kelly et al., 2018 [8])+

Mental health benefits of walking	Evidence	Strength of evidence for benefits
Depression	Five systematic reviews found evidence to suggest that walking may be beneficial in both the prevention and treatment of depression. For example, one included systematic review and meta-analysis of RCTs (eight studies; 341 people) found that walking can treat clinical depression (effect size -0.86, large effect size) [35].	Systematic review level (interventions & observational)
Anxiety	Based on 14 studies (five cross-sectional, one prospective, five interventions, four acute studies), the authors found evidence that walking is beneficial for preventing and treating anxiety.	Consistent study level (interventions & observational)
Self-esteem	Evidence from 11 studies (two cross-sectional, seven interventions, four acute studies) suggests that walking interventions can have a positive effect on self-esteem but observational findings were limited.	Inconsistent study level (interventions & observational)
Psychological stress	The authors found emerging but limited evidence from six studies (two cross-sectional, three acute studies, one intervention) that walking is associated with lower psychological stress in observational studies, and that walking could be used as a potentially promising intervention to decrease psychological stress.	Study level (interventions & observational)
Psychological well-being	The evidence base is limited but promising, with three cross-sectional studies and one prospective study identifying positive relationships between walking and psychological well-being. The findings from the intervention studies are mixed with only two of seven studies demonstrating positive effects on psychological well-being compared with control groups.	Inconsistent study level (interventions & observational)
Subjective well-being	11 studies (four cross-sectional, two prospective cohort, five acute studies) indicated an association between walking and subjective well-being. The only long-term intervention study was inconclusive and further studies are clearly needed.	Inconsistent study level (interventions & observational)
Resilience	No published journal articles were identified addressing the association between walking and resilience. However, there is emerging evidence suggesting a relationship between physical activity and resilience.	-
Social isolation and loneliness	The evidence base for walking on social isolation and loneliness is limited. One cross-sectional study found a significant positive association between frequency of contact with neighbours, neighbours social support and neighbourhood involvement and participation in walking behaviour, whilst four intervention studies showed mixed evidence.	Fragmented (interventions & observational)
Neurological conditions [1]	Reduced risk of dementia, improved cognitive function, reduced feelings of anxiety and depression in healthy people and in people with medical conditions, reduced incidence of depression, and improved cognition in people with dementia.	Systematic review level (observational)

*Total number of people included for each outcome and study quality not reported in review.

+As a scoping review, there was no quality assessment of the included studies.

The physical health benefits of cycling

The **direct evidence** base for the physical health benefits of cycling is not as large as for walking. In large part this is because in most countries there is less cycling than walking at a population level, and therefore fewer opportunities to study and observe the benefits (or harms). However, cycling is a good example of moderate to vigorous physical activity, and the evidence on moderate to vigorous activity as a whole is very strong. Thus there is strong **indirect evidence** indicating a range of health benefits (see section 4). The following section will outline the available **direct evidence** on the physical health benefits of cycling.

Our search strategy identified 4 systematic reviews, 1 meta-analysis of cohort studies, 1 non-systematic review, and 5 individual studies (3 cohort studies, 1 prospective study, and 1 RCT), which found evidence that cycling can reduce the risk of all-cause mortality, cardiovascular disease and type II diabetes. There was also evidence to suggest that cycling can improve disease risk factors, including cardiorespiratory fitness and body composition.

Only 2 studies were identified for blood pressure and 1 for blood lipids, making it difficult to form strong conclusions. The review did not identify any evidence on the effect of cycling on haemostatic, inflammatory and immune function markers, or for coronary heart disease. The evidence for the benefits of cycling on these outcomes is summarised below in Table 5 and Table 6.

Table 5 Effect of cycling on disease incidence, disease mortality, and all-cause mortality

Potential benefits of cycling	Findings	Strength of evidence for benefits	Quality assessment (systematic reviews only)
All-cause mortality	Two cohort studies found that cycling was associated with a 21% reduced risk of all-cause mortality in 67,143 women [36] and a 28% reduce risk of all-cause mortality in 30,640 adults [37]. A meta-analysis (search date 2013) of seven cohort studies (187,000 people) found that a cycling level corresponding to WHO guidelines of 150 minutes of moderate physical activity per week was associated with a 10% (95% CI 4 to 17%) reduced risk of all-cause mortality, compared with no cycling. A dose-response relationship of cycling was also estimated, which suggested that physical activity benefits per unit of cycling are about twice as high for the first 1-2 hours of cycling per week, compared with significantly more time spent cycling [14].	Systematic review level (cohort)	From 7 studies, mean score was 7.7/9 [14]
Cardiovascular disease	A review (search date 2018) identified cohort studies (12 studies; 722,407 people) and found that seven out of 12 studies reported a statistically significant reduced risk of cardiovascular disease incidence and/or mortality with cycling compared to low or no cycling, and five studies found no significant associations [38].	Review level (cohort)	No quality assessment
Cancer	A review (search date 2018) identified cohort studies (nine studies; 1,074,480 people) and found that six out of nine studies found no statistically significant association between cycling and cancer incidence, while three out of nine studies found that cycling was significantly associated with cancer incidence and mortality compared with no cycling [38].	Review level (cohort)	No quality assessment
Type II diabetes	A review (search date 2018) identified cohort studies (four studies; 193,273 people) and found that two out of four studies found a statistically significant association between cycling and reduced risk of type II diabetes compared with no cycling [38].	Review level (cohort)	No quality assessment

Table 6 Physical health benefits of cycling

Potential benefits of cycling	Findings	Strength of evidence for benefits	Quality assessment (systematic reviews only)
Cardiorespiratory fitness	Three reviews were identified that reported associations between cycling and cardiorespiratory fitness. The first review (published 2011) identified two RCTs and one controlled clinical trial and found evidence to suggest that cycling benefits cardiorespiratory fitness in adults. The same review found inconclusive evidence for benefits in adolescents (two cross-sectional studies, one prospective study) [39]. Another review (search date 2018) found four RCTs (281 people) of cycling to school/work interventions and reported that three out of the four studies found that the intervention groups significantly increased cardiorespiratory fitness [38]. The final review (search date 2012) identified four cross-sectional and one prospective study (10,918 children) and found that cycling benefits cardiorespiratory fitness in young people [25].	Systematic review level for adults; inconclusive for children (RCTs, controlled clinical trial, cross-sectional and prospective)	Adults – predominantly strong; children – moderate [39] Predominantly moderate quality [25] No quality assessment [38]
Blood pressure	A cohort study (23,732 people) found that cycling to work at baseline was associated with lower odds of hypertension compared with passive travel after adjusting for confounding factors [40]. A review (search date 2018) also identified one RCT (48 adults) which found no change in blood pressure following a cycling intervention [38].	Inconclusive (cohort and RCT)	No quality assessment
Blood lipids	A cohort study (23,732 people) found that cycling to work at baseline was associated with lower odds of hypertriglyceridemia (OR=0.85, 95% CI 0.76 to 0.94) compared with passive travel after adjusting for confounding factors [40].	Fragmented (cohort)	-
Body composition	A systematic review (search date 2010) identified three studies (15,062 people) reporting an association between cycling and lower body weight in adults [41]. A further review (search date 2018) identified cohort studies (four studies; 61,272) and one RCT (48 people) and found that three out of the four cohort studies showed that cycling is significantly associated with reduced risk of developing obesity and the RCT significantly decreased body fat compared with no cycling [38]. In children, a prospective study of 890 children found that cycling to school was associated with lower body weight [42]. A randomised cycling intervention targeting young people with Down Syndrome (46 young people) found that the intervention led to reductions in BMI and percentage body fat amongst those who successfully learned how to ride a bicycle, however 44% of the intervention group did not learn how to ride a bicycle during the training period [43].	Review level (interventions & observational)	Mean score 3.7/10 [41] No quality assessment [38]
Musculoskeletal health	A systematic review (search date 2012) of observational and intervention studies (31 studies; 2922 people) examined the evidence on cycling and bone health. The authors concluded that "from our	Systematic review level	Mean score 4/7

	comprehensive survey of the current available literature...road cycling does not appear to confer any significant osteogenic benefit." [44]	(interventions & observational)	

The mental and neurological health benefits of cycling

No review-level evidence for the mental or neurological health benefits of cycling was found. Thus there are insufficient data to generate an evidence table as has been compiled here for walking, and for the physical health benefits of cycling.

Of the studies that were identified there was 1 prospective study, 4 cross-sectional studies, 1 non-randomised intervention and a qualitative study. They provided indications that cycling could benefit mental wellbeing and sickness absence from work [45], psychological stress [46, 47], subjective well-being [48], and social isolation and loneliness [49]. There was mixed evidence for cycling and health-related quality of life [50, 51]. Only 1 of the 7 studies were considered to have met the inclusion criteria, so conclusions about the specific mental health benefits of cycling have not been made.

While there remains insufficient **direct evidence** specifically pertaining to cycling, there is strong **indirect evidence** for the benefits of leisure time physical activity and MVPA on mental health. Cycling can be considered a good example of these behaviours.

Active travel and active commuting: the health benefits

There is a body of evidence investigating the health benefits of active travel and active commuting, where walking and cycling (and other forms of active transport eg scooting) are combined in studies and assessed as a single behaviour. This is summarised below.

Physical health benefits of active travel and commuting

A meta-analysis (search date 2007) of cohort studies (8 studies; 173,146 people) demonstrated an 11% (95% CI 2 to 19%) reduced risk of adverse cardiovascular outcomes with active commuting compared with passive commuting [52]. The protective effects of active commuting were more robust among women than in men. A nested case-control study (204 heart attack cases and 327 matched controls) found that car commuting was significantly associated with increased risk of heart attack (OR 1.77, 95% CI 1.05 to 2.99).

Inflammatory and haemostatic markers explained a substantial proportion of the reduction in heart attack risk related to active commuting in this population [53]. Similarly, a large cohort study (28,334 people) found that active commuting was significantly related to reduced risk of heart failure in women but not in men [54].

A cohort study (219 women) analysed travel behaviour in pregnant women and found that those who kept travelling actively during pregnancy gained less weight than those who became less active [55]. An RCT (130 inactive obese women) found that the active commuting group decreased their C-reative protein (high levels are a marker of inflammation) by approximately 30% from baseline to 6 months. No effects of the activity were observed on the haemostatic compounds of fibrinogen, vWF, t-PA, PAI-1 or the t-PA/PAI-1 ratio within or between groups [56].

Health benefits of active travel have also been identified in young people. A systematic review by Lubans *et al* (search date 2009) identified 27 studies and found positive associations between active travel to school and cardiorespiratory fitness (4 cross-sectional, 1 prospective study; 13,459 children), with mixed evidence for active travel on body composition (24 cross-sectional, 1 prospective; 79,545 children) [57].

A systematic review (search date 2007) of 18 studies (16 cross-sectional, 2 prospective; 42,977 children) found no association between active travel and body weight in children [58]. This was supported by a further systematic review (search date 2008) of 10 studies (9 cross-sectional, 1 prospective; 6044 children), which also found no association between active travel and body weight in children [59].

Mental health benefits of active travel and commuting

A meta-analysis by White *et al* [60] (search date 2015) of cross-sectional and prospective studies (14 cross-sectional, 1 prospective; 29,774 people) found a positive association between transport physical activity and mental health in 7 studies, with stronger associations found for active travel to and from work compared with travel for an unidentified reason or where all trips were measured together. There was no association with mental ill-health.

Of note, a number of studies do not meet the criteria for inclusion in the evidence summary. This includes cross-sectional evidence suggesting that active travel can have a positive effect on psychological well-being [61, 62], subjective well-being [62, 63], depressive symptoms [64], and physical well-being [65], and 1 cross-sectional study that found no association between transport physical activity and happiness [66].

6. Do health impacts differ by domain and type of walking and cycling?

Walking and cycling can be classified as occuring in 1 of the 4 main domains of physical activity [67]. Walking and cycling usually occur in transport, leisure and exercise, or as part of work and occupation (see Figure 2). In terms of transport, walking can be part of multimodal trips, and while this is less common with cycling, the train-bicycle combination has substantial potential. In which category different people do most of their walking and cycling varies by context and by demographic factors, including age and gender.

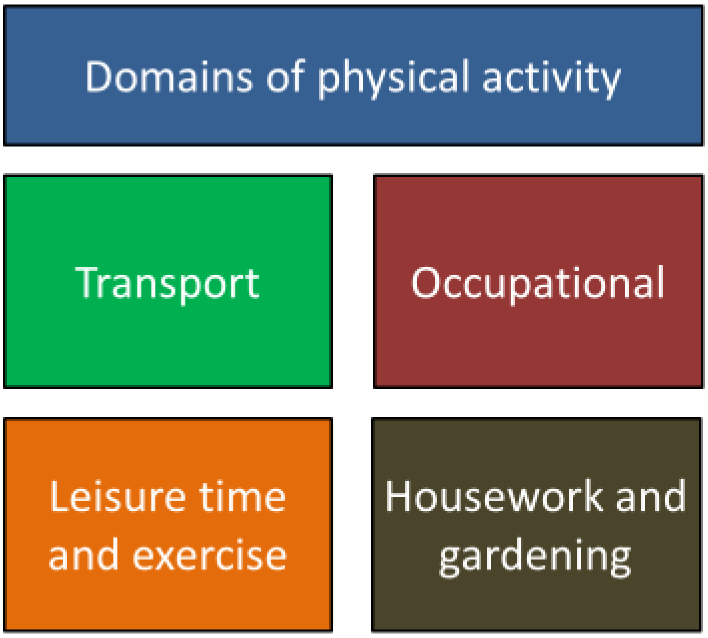

Figure 2. The 4 main domains of physical activity. Walking and cycling are usually classified in 3 of the 4 (Transport, Occupational, or Leisure time and exercise). Where walking is part of housework and gardening, this would normally be incidental or of very short duration.

Domains of walking and cycling

Do different domains of walking and cycling have differing impacts on health? Separating out the studies by both modality (walking and cycling) and domain dilutes the evidence. This risks either reporting random variation in study results as real differences, or treating absence of evidence on a specific behaviour domain as indicating a genuine lack of knowledge. In this way we may risk unnecessary doubt.

Thus instead of separating out the evidence it might be better to consider why, for example, walking or cycling to work might have different health effects to walking or cycling for leisure? Considerations may include (i) the pace, (ii) the exposure to pollution, (iii) injury risk, (iv) the proximity to green or forest space, or (v) the presence of social company. Personal preference and prior experiences may also play a part. The frequency and likelihood of the behaviour being habitually sustained are perhaps most likely to impact the long term health outcomes. Added to that, walking, cycling, and car ownership can be influenced by socio-economic status (SES) which could confound any detected relationships. Considering all these factors, the current epidemiological evidence base is simply not large enough to address any domain differences in a meaningful way yet.

There are 2 main points to emphasise. Firstly, in section 5 the **direct evidence** showed numerous positive health effects of walking and cycling. These studies came from a spectrum of types and domains, so the interpretation of the evidence is that any type of walking or cycling at a sufficient intensity, duration, and frequency is likely to benefit health. Secondly, there are a number of research gaps that, if addressed, will deepen our understanding of how different types of walking or cycling may have differential effects, and how effects may change across the lifecourse[3].

In summary, there is not (yet) sufficient evidence to make strong conclusions that one domain of walking or cycling is more beneficial than another. This is a priority area for greater understanding, in order to inform policy and strategy for greatest societal benefit.

Do benefits vary by pace and intensity?

In short, yes, but the implications for policy and health promotion are not simple.

The physiology of walking and cycling means that there are greater potential physical health benefits if conducted at greater speed/pace as the intensity will be higher [68, 69]. While the observational evidence can be confounded by fitter, healthier people being able to walk/cycle faster, the experimental evidence supports these findings [70].

Pace and intensity are relative rather than absolute concepts. One person’s 3mph walk may be a greater relative effort than another person’s 4.2 mph, and the 3mph walker may therefore derive greater relative health effects. This is because there is a spectrum

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[3] For example Kelly et al., (2018) reported preliminary evidence that type, context, and environment of walking seem to impact magnitude of mental health benefits.

of fitness across the population that varies by factors such as leg length, age, weight status, or history of activity.

The complexity comes in considering how best to use this information. The people who stand to benefit the most from eg walking are those who are most unfit, likely with pre-existing medical conditions and/or a history of inactivity and other unhealthy lifestyle behaviour [70]. It may be that a “public health message” emphasising greater pace and intensity would be less motivating and more unattainable than one that said “any walking will improve health”.

Finally while the physiology on the physical health benefits is supportive of greater pace [70], it is less clear whether greater pace is better for mental health [8]. If mental health is impacted by social contact or enjoying the environment, pace may have no role, or even a negative role if it makes the activity less enjoyable.

The evidence base does not answer these questions at present, and so how to most effectively utilise pace in walking and cycling promotion is not known. Therefore, while physiologically correct, it is not known if pace should be included or emphasised in walking and cycling promotion.

7. What is known about walking-cycling health benefits by age (across the life-course)?

As children, adults, and older adults often experience different health outcomes and conditions, it may be expected that the health benefits of walking and cycling would vary by age.

As is the case for physical activity in general, there are fewer associations between walking and cycling and disease end points in children. This is because many of the chronic diseases associated with low activity do not manifest in childhood, but rather in adulthood. As a result, risk factors (eg cardiometabolic fitness) may be more informative to study, and for young people, cycling has been shown to benefit cardiorespiratory fitness [25, 71]. Both walking and cycling are beneficial for cardiorespiratory fitness in adults [24, 39].

For adults, age was not found to significantly moderate associations between walking and cardiorespiratory fitness, blood lipids or body composition [24]. However, it is likely that walking and cycling may be of particular benefit for some health outcomes in older adults. It should be noted that for most diseases risk increases with age, so the same relative risk reduction in disease risk has a much greater absolute risk reduction at older ages. The big exception here is mental health outcomes, with burden greater at younger ages.

A systematic review of 30 modelling studies estimated that middle-aged and older adults (>45 years) would benefit more by shifting to active travel than younger people [72]. However, the review was not able to determine if those who were active at younger ages were more likely to be active at older ages. There is some evidence that physical activity behaviour tracks from childhood to adulthood [73]. It is therefore plausible that children and adolescents who walk and cycle are more likely to become adults who are normalised to walk and cycle, increasing the rationale for starting at young ages.

For musculoskeletal health, there is some indication from systematic reviews that walking could be particularly beneficial for older adults or adults with impaired musculoskeletal health, with evidence for improvements in postmenopausal women and adults with chronic back pain, but not in healthy adults (see Table 3).

Overall, there are benefits of walking and cycling across the lifecourse. Better understanding of this may be of particular interest to those delivering and planning for health and social care.

8. What is known about the benefits by socioeconomic status?

For adults in England, a nationally representative survey found no substantive difference in walking levels between the most and least deprived areas in men. For women, there were no significant differences by deprivation for walking levels in insufficiently active women, however active women in the most deprived areas walked significantly more than active women in least deprived areas [74]. In older adults, data from the English Longitudinal Study of Aging found that walking speed was significantly faster in the least deprived areas compared with the most deprived (0.91 m/s compared with 0.75 m/s at age 70 years). This declined faster with age in adults in the least deprived areas. However the gaps in walking speed between the most and least deprived areas did not close [75].

In children, girls in the most deprived areas cycled significantly less than girls in less deprived areas. There were no significant differences in cycling levels for boys, or for walking levels in boys or girls [76]. Another study based in England found that children who walked to school were more likely to live in a deprived area compared with children who did not walk or cycle to school [77].These findings may have implications for cycling policy actions and priorities.

The benefits of increasing walking and cycling have also been estimated by SES. Tainio and colleagues modelled mortality impacts of replacing short car trips with cycling by age, gender and SES. They found that benefits are greater for less deprived SES groups, largely because these groups were conducting more car trips at the outset. These findings suggest that to get full benefits across the population and SES spectrum, there is a need to consider more than just car trips [78], although the harms of car use (eg pollution, injury risk) were not considered. Conversely, a systematic review (search date 2014) identified 2 relevant modelling studies and these estimated that disadvantaged ethnic groups would benefit more from active travel than the general population [72]. This conclusion was related to higher incidence of chronic disease in disadvantaged ethnic groups.

The Impacts of Cycling Tool (ICT) (www.pct.bike/ict) provide both a data visualisation of the National Travel Survey and models the potential impacts of non-cyclists having the same likelihood to cycle a trip of a given distance as existing cyclists. Results are available for each English region and by socioeconomic group, age group, gender and ethnic minority status. Of note it can be seen that the proportion of trips that are made by walking is higher for those in lower SES groups. It identified that for people of low SES and for ethnic minority women, cycling could lead to notable travel time savings. In the population as a whole, around 57% of the trips switched would be slower by bike.

Among women just over 50% of trips would be faster by bike. Among non-white women and the never worked and long-term unemployed over two-thirds of trips would be faster by bike.

Based on the available evidence, there is a need to consider the potential for walking and cycling policy actions, and interventions to address health and wider social inequalities.

9. What is known about the benefits by disability and long-term health conditions?

In England, people with a physical disability were found to be approximately 50% less likely to have cycled in the past 4 weeks than people without a physical disability [79]. However, the variation between local authorities is greater still and disabled people in higher cycling areas are more likely to cycle than non-disabled people in low cycling areas [80]. A qualitative study found that cycling infrastructure is not adequately inclusive for disabled populations and significant barriers to disabled cycling remain in the UK, predominantly relating to cost and infrastructure. The authors noted a lack of research on disability cycling, with further research needed to better understand how to support people with disabilities to cycle for different purposes (eg travel, recreation) [81]. Further evidence also highlights the exclusion of people with disabilities in transport and cycling strategies in London [80].

Few studies have investigated if the benefits of walking and cycling are different for disabled people. There is cycle ergometer (stationary bike) evidence for positive impacts on affect, anxiety, gait, pain (in osteoarthritis), pain-related disability, and health-related quality of life in adults with intellectual disabilities, but this cannot necessarily be extrapolated to cycling for leisure or transportation [1].

This limited evidence base on walking and cycling [82] suggests an urgent need for further research to understand potential benefits of, or inequalities in access to, walking and cycling for disabled people.

There are an additional set of questions about what walking and cycling participation might look like across a range of disabilities, mobilities, and conditions. There may be particular differences between physical and mental disabilities. The bodily movements and muscle groups involved have the potential to impact the health effects experienced. Greater understanding is required.

Whilst there is not yet specific **direct evidence** for walking and cycling, there is considerable **indirect evidence** in that physical activity is beneficial for people living with long-term conditions [1]. Given that walking and cycling contribute to total physical activity, it is likely that walking and cycling would be beneficial for people with long-term conditions, especially as they are on average less physically active overall.

10. Benefits for the wider population

In addition to the physical and mental health benefits of walking and cycling to the individual, there is evidence that walking and cycling can have wider population benefits including reductions in air pollution, noise and economic benefits. In other words, it is not just the individuals doing the walking and cycling that stand to benefit. A 2016 report by PHE, *Working Together to Promote Active Travel,* detailed a number of wider benefits including improvements in local air quality and in social cohesion, along with reductions in traffic congestion, carbon emissions, and road casualties [83]. Further details are discussed below.

Air pollution

A systematic review (search date 2014) of modelling studies (primarily from Europe) identified 14 studies that estimated health benefits to the general population from increased active travel and reduced car use. The included studies identified reductions in a range of outcomes including all-cause mortality, respiratory disease, cardiovascular disease, cancer, adverse birth outcomes, activity-restriction days, and productivity loss from increased active travel and reduced car use in the general population [72]. A report by Sustrans estimated that meeting the targets to double cycling and increase walking set out in the Government's CWIS in England would lead to savings of £567 million annually from air quality alone and prevent 8300 premature deaths each year [84].

Noise

A systematic review identified 3 studies investigating potential health impacts of noise exposure to the general population with a shift to active travel. The included studies estimated reductions in noise costs. However, the potential health impacts that contribute to this were not explicitly quantified [72].

Economic costs to the NHS

Previous work for Public Health England has estimated the cost to local commissioning groups of physical inactivity. The most recent estimates are that physical inactivity costs the NHS more than £450 million a year [85]. This is likely to be an underestimate, because it only considered those not meeting minimum recommended physical activity levels and only some of the diseases likely to be affected by physical inactivity were covered. Notably, dementia was not included. Costs were largest for diabetes followed by coronary heart disease, then cerebrovascular disease, then breast cancer and colorectal cancer [85]. As described in previous sections, promoting walking and cycling address inactivity and contribute to reducing these economic costs.

11. What about adverse effects?

Injury risks while walking or cycling

Trade-offs between injury risk and physical activity benefits have generally been found to be positive at the population level [72]. That is to say, the health benefits of walking and cycling in a given population are greater than the health risks and harms. Modelling studies suggest that the benefit-to-harm ratio is generally better at older ages, as disease risks increase with age [86] faster than injury risks increase. For example, a study of the London cycle hire scheme estimated much bigger benefits from cycling in central London for older people.

Road traffic fatality rates can be measured per population but are better represented as occurring per distance travelled as time spent travelling or per trip. Because walking is slower than cycling and cycling is often slower than driving, a per time based measure makes walking appear relatively safer than a distance based one. In England fatality rates per km travelled are higher for pedestrians (36.7 fatalities per billion km in 2010-2012) and cyclists (20.8 fatalities per billion km) than driving (2.8 fatalities per billion km) [87]. Rates vary substantially by age and gender. For young men (17-20 years), rates are particularly high when driving and similar to the risk whilst cycling. For walking generally, fatality rates are higher for men than for women. By age, risks appear to be J shaped for cycling; that is falling toward middle age and increasing faster at older ages. The risks of walking increase exponentially with age.

Statistics on hospital admission rates per billion km show a slightly different picture. Generally rates are higher for cyclists than for pedestrians at younger ages (under 40) and higher for pedestrians at older ages [88]. However, the data are likely to be less robust than for fatalities.

Driving poses a greater risk to others than walking or cycling. However, even when accounting for all the people involved in road traffic collisions the rates per million hours were still lower for drivers (in 2011-2013 0.257 for men and 0.127 for women) than for cyclists (0.425 for men and 0.216 for women) [89] . One limitation of this analysis is that the distance driven by car includes relatively safe miles on the motorway and this makes comparison between risks while driving on other roads and risks whilst walking and cycling more difficult. Generally, risks are higher for all modes in rural areas.

There is systematic review evidence from 2017, with 15 studies to suggest that when the number of pedestrians and cyclists increases, there is a less than proportional increase in the number of collisions and injuries involving them [90]. This suggests a safety-in-numbers effect. Although mechanisms are still debated, the effect findings are relatively consistent. Safety in numbers probably occurs in addition to the effects of other road safety factors. One study in England found that for cyclists overall injury risk increased between 2001 and 2011 despite a small increase in cycling and a safety in numbers effect being identified [91]. A safety in numbers effect by itself would still mean that total cyclist and pedestrian injuries increase with increases in use. However, as risk is also affected by motor vehicle volume, a mode shift to walking and cycling can lead to a fall in total injuries. A systematic review identified 21 studies investigating the effect of active travel and injury and fatality risk, specifically in relation to traffic related injuries and fatalities. Fourteen out of the 21 studies estimated an increase in risk of road traffic injuries or fatalities. Six studies estimated a decreased risk, and 1 estimated no change in traffic fatalities with increased active travel [72]. However, comparing injury/fatality data between cycling and car journeys is notably challenging [92].

According to recent figures from the UK Department for Transport, 69% of women and 56% of men in England feel it is too dangerous to cycle on the roads [93]. Fear relates both to experience or awareness of actual collisions and also to the far more common 'near misses' [94]. There is likely to be a smaller effect on discouraging walking, but this is less well studied.

Exposure to air pollution

Air pollution causes a substantial population health burden. Physical activity can increase exposure to air pollution through changes in inhalation rate and changes in air pollution concentrations in the location of activity. Being physically active increases the inhalation rate, which can lead to a higher dose of air pollution penetrating lungs [95]. While this is true for all forms of activity, the impacts will be greater for those in more polluted environments. Air pollution whilst travelling is an important factor, particularly in urban environments as air pollution concentrations are higher in traffic. A review of European studies found that pedestrians are on average less exposed than car and bus users and cyclists, and car users are more exposed than cyclists on average. Cyclist and bus rider exposure contrasts depend on the type of pollutant, but are similar [17].

Several studies have assessed the short term impacts of air pollution and physical activity [96-98]. Short-term studies suggest that air pollution can reduce the benefits of physical activity, but that the benefits are still greater than the risks. For example, in a recent study in London volunteers walked in a polluted environment. Reduced cardiorespiratory benefits were observed among those aged 60 years and older. [99]. Long-term cohort studies suggest that physical activity could protect from the harmful effects of air pollution, and that air pollution, at the levels seen in England, will not significantly modify the benefits of physical activity amongst adults [100-103].

Several modelling studies have compared the risks and benefits of walking and cycling in the urban environment and all of them have concluded that the benefits of physical activity outweigh the risks of air pollution [72]. More recently, a study looked specifically at the long-term risk-benefit trade-offs of walking and cycling-related physical activity and air pollution in multiple locations of the world, and concluded that in England the benefits clearly outweigh the risks [104].

There is also a small, but growing, literature on the impact of air pollution on people’s willingness to do physical activity [105].

12. Models and tools

Various tools exist to estimate the health impacts of increasing population levels of walking and cycling. The WHO Europe Heath Economic Assessment Tool (HEAT) heatwalkingcycling.org/#homepage estimates health gains from changes in walking or cycling, and new modules allow estimation of how much of this gain might be offset by higher injury risks and increased inhalation of air pollutants. The health gains are expressed as premature deaths prevented and the results monetised using the statistical value of a life.

In England, the Department for Transport (DfT) has produced guidance on modelling health impacts of changes in walking and cycling. These include an approach related to HEAT, but that estimates health impacts as changes in the 'reduction of years of life lost due to physical inactivity' trid.trb.org/view/1485096. The DfT also includes recommended values for changes in sickness absence from increased walking and cycling. trid.trb.org/view/1485096.

The DfT has also funded the open source Propensity to Cycle Tool (PCT) that estimates the cycling commuting potential and corresponding physical activity gains at an area and route level in England [13]. The PCT is available at www.pct.bike. The PCT uses a modified version of the HEAT approach accounting for local authority mortality rates and the age distribution of the population.

Results from local authority level analysis show that if English people were as likely to cycle a trip, allowing for trip distance and hilliness, as people in the Netherlands, then there would be high cycling potential in all local authorities. While England is hillier than the Netherlands, English commutes tend to be shorter. This scenario showed that if English people became as likely to cycle a trip of a given distance as Dutch people, nearly 1 in 5 (18%) would cycle to work - an almost 6-fold increase. Across England, every local authority would see at least 1 in 15 commuters cycling to work, with a third seeing cycle commuting rates of 20% or more. The PCT also includes an *Ebikes* scenario that builds on the *Go Dutch* scenario and looks at the additional cycling potential if people had Dutch propensity plus widespread access to electric bikes ('ebikes'). Ebikes enable people to cycle that bit further and tackle hills more easily. Under the *Ebikes* scenario, more than 1 in 4 commuters (26%) would cycle all the way to work. Even in the most hilly areas, like West Devon, at least 1 in 7 commuters might cycle [106]. The PCT is recommended for use in the CWIS [7] and meets a need identified in the recent NICE guidance to identify areas where there is high potential to increase active travel. [www.nice.org.uk/guidance/ng90/chapter/Recommendations]

Another tool funded by the UK Department for Transport is the Impacts of Cycling Tool (www.pct.bike/ict) [107]. This estimates multiple outcomes if non-cyclists became as likely to cycle a trip of a given distance as existing cyclists. Outcomes include premature deaths prevented, years of life gained, changes in physical activity levels, greenhouse gas emissions, and time savings or losses.

The interface allows users to look at the impacts on population subgroups by age, gender, ethnicity and socio-economic group. The modelling study finds that if the proportion of the English population who cycle regularly increased from 4.8% to 100%, then there would be a nearly 10% reductions in car miles and passenger related CO_2 emissions, along with reductions in premature mortality of 7.5% to 10.8% (varying by age and gender). If the new cyclists had access to ebikes, then mortality reductions would be a bit smaller (7.0% to 10.3%), while the reduction in car miles and CO_2 emissions would be greater (13%). Generally health benefits were slightly greater among men than among women in relative terms, and notably greater in absolute terms. This is due to a combination of the different risk profiles of men and women, differences in trip patterns, and that men are more likely to cycle a longer trip distance than women on average. Absolute benefits increased rapidly with age, as disease risks are higher at older ages and - to a lesser extent - because other types of physical activity are less common at older ages.

While the PCT focuses on scenarios of behaviour change, a common need in transport planning is to simulate impacts of interventions change. With the aim of meeting this need, the Cycling Infrastructure Prioritisation Toolkit (CyIPT) was funded by the DfT's Innovation Challenge Fund. The estimated costs and potential benefits of each scheme is estimated and visualised in a web application hosted at www.cyipt.bike/ (password protected) to inform the decision-making process. Uptake is modelled based on an analysis of change in cycling rates and infrastructure between 2001 and 2011 in areas that saw investment in cycling.The CyIPT is being used by Local Authorities and others to prioritise schemes within overall cycling strategies developed using tools such as the PCT and local knowledge.

The NICE physical activity return on investment tool (www.nice.org.uk/about/what-we-do/into-practice/return-on-investment-tools/physical-activity-return-on-investment-tool) is an Excel model developed to help decision making in physical activity programme planning for local authorities. Unlike the PCT or ICT, it aims to model the impact of interventions using default or user-provided values on the cost and effectiveness of the intervention. Interventions can be combined together to compare the relative cost effectiveness. Unlike HEAT, the PCT, or ICT it does not model the effect of physical activity directly on mortality, but through 3 diseases: coronary heart disease, stroke, and type 2 diabetes. Also, unlike the other tools, it does not use a continuous dose response function but represents physical activity as 3 levels (inactive, low activity, and sufficiently active) [108].

13. Lessons for promoting walking and cycling

This section briefly considers lessons, opportunities and suggestions for actions for the health and social care sector in terms of promoting walking and cycling. Public health should be about helping to build a health-promoting environment and society. This includes building a society where walking and cycling are the norm. The UK Government has a stated ambition for “cycling and walking to become the norm by 2040” [109] and will target funding at innovative ways to encourage people onto a bike or to use their own 2 feet for shorter journeys. This includes specific objectives to double cycling, reduce cycling accidents, and increase the proportion of 5-to-10 year-olds walking to school to 55% by 2025” [101]. The plan for how to achieve this is laid out in the CWIS [7].

A 2017 Report by PHE, *Spatial planning for health: An evidence resource for planning and designing healthier places* illustrated the linkages, and strength of evidence, between spatial planning and health based on the findings from an umbrella literature review of the impacts of the built environment on health [110].

This report identified 4 key principles for promoting healthy transport:

1. Provision of active travel infrastructure;
2. Provision of public transport;
3. Prioritising active travel and road safety;
4. Enabling mobility for all ages and activities.

In 2012 the National Institute for Health and Clinical Excellence (NICE) published public health guidance on promoting walking and cycling [111]. This covered policy and planning, local programmes schools, workplaces and the NHS. In relation to the health sector, this guidance stated that the NHS as a large employer should encourage walking and cycling to access its sites among staff, visitors, and patients. It emphasised the importance of providing for inclusive walking and cycling, including disabled people. The relevant information is presented in Table 7.

Table 7 2012 NICE guidance recommendations for promoting walking and cycling [111]

Recommendation 1 High-level support from the health sector

Who should take action?

- directors of public health
- public health portfolio holders in local authorities
- clinical commissioning groups

What action should they take?

- ensure a senior member of the public health team is responsible for promoting walking and cycling. They should support coordinated, cross-sector working, for example, by ensuring programmes offered by different sectors complement rather than duplicate one another. The senior member should also ensure NICE's recommendations on physical activity and the environment are implemented
- ensure the joint strategic needs assessment, the joint health and wellbeing strategy and other local needs assessments and strategies take into account opportunities to increase walking and cycling. They should also consider how impediments to walking and cycling can be addressed
- ensure walking and cycling are considered, alongside other interventions, when working to achieve specific health outcomes in relation to the local population (such as a reduction in the risk of cardiovascular disease, cancer, obesity and diabetes, or the promotion of mental wellbeing [1]). These include outcomes identified through the joint strategic needs assessment process
- ensure walking and cycling are included in chronic disease pathways
- ensure all relevant sectors contribute resources and funding to encourage and support people to walk and cycle
- where appropriate, ensure walking and cycling are treated as separate activities which may require different approaches
- ensure walking and cycling projects are rigorously evaluated. This includes evaluating their impact on health inequalities

Recommendation 10 NHS

Who should take action?

- clinical commissioning groups
- national commissioning board
- primary and secondary healthcare professionals

What action should they take?

- incorporate information on walking and cycling into all physical activity advice given by health professionals. (See also NICE's recommendations on 4 commonly used methods to increase physical activity.)

- ensure walking and cycling are among the options provided by the ‘Let's Get Moving’ physical activity care pathway
- ensure people who express an interest in walking or cycling as a way of being more physically active are given information about appropriate national and local initiatives. Also provide individual support and follow-up (see recommendation 7)
- direct people with limited mobility to specialist centres where adapted equipment, assessment and training are available for walking and cycling
- ensure walking and cycling programmes link to existing national and local initiatives

14. Limitations

There are a number of limitations that should be acknowledged.

In relation to the evidence base, far more studies have focused on leisure activity or total activity than on walking or cycling specifically. This is because of the interests of researchers, the measurement tools or data available, and also because cycling is a less common regular activity in most countries where studies have been conducted. The studies of walking and cycling provide more evidence on broad outcomes such as all-cause mortality than on individual disease mortality. This is partly because there are more total deaths in the studies than from any 1 cause, so the statistical power is greater. In large population cohorts it is also generally easier to assess hard disease outcomes from eg death registers than it is to assess risk factors such as high blood pressure. This also biases the available evidence.

There is generally more observational prospective evidence than long-term trial evidence, as trial designs are far more expensive and harder to control, especially over a number of years. As a result, it is difficult to find evidence of the 10- or even 5-year effects of increased walking from a randomised trial.

These considerations need to be held in mind when reading the specific evidence. Lack of, or incomplete evidence on walking and cycling for a specific outcome will often be because no-one has sufficient data to study it well. However, where there is good evidence that physical activity impacts this outcome, then there is general scientific consensus that will most likely apply to walking and cycling as exemplar types of physical activity. At present this **indirect evidence** is more abundant, and of higher quality, than the **direct evidence** for walking and cycling.

In relation to the methods, this was a rapid scoping review conducted in a limited time frame. This restricted the ablity to assess all aspects of study design and quality. For example, the report was not in a position to say which of the relationships or associations described were independent from engagement in other physical activity (independent associations allow stronger inference of the modal specificity of walking and cycling). There was also only time to search a limited number of databases. Further, there was not scope to conduct meta-analysis on each outcome to find the pooled effect.

It can be considered a strength that the report has focused on systematic reviews and meta-analyses, followed by other review designs and high quality studies. This has allowed summarising of the evidence base for a high number of outcomes and questions. It has also been possible to highlight areas where the evidence base has gaps, and future research could be prioritised.

15. Conclusions and recommendations

There is strong evidence that physical activity improves physical and mental health, and that walking and cycling make important contributions to overall physical activity levels. A growing body of **direct evidence** supports specific physical and mental health benefits for both walking and cycling.

Increasing walking and cycling therefore has the potential to substantially improve individual and population health, and thus benefit health and care systems.

The evidence set out in this rapid evidence review will help make the case for appropriate levels of funding for further active travel interventions. To increase population walking and cycling, and to realise the associated benefits for population health and health and care systems, there is a need to provide environments and opportunities that support walking and cycling. Such environments should be accessible to all, with particular attention to ages, socioeconomic status, and people with disabilities and long-term conditions.

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Appendix 1: The Chief Medical Officers' Physical Activity Guidelines

Individual physical and mental capabilities should be considered when interpreting the guidelines.

Adults Aged 19-64 years

Adults should aim to be active daily. Over a week, activity should add up to at least 150 minutes (2 ½ hours) a week of moderate intensity activity. Comparable benefits can be achieved through 75 minutes of vigorous intensity activity spread across the week, or combinations of moderate and vigorous intensity activity.

This volume of activity can be accumulated in different ways. Higher intensity activity for shorter amounts of time or a mixture of moderate, vigorous and high intensity activities will provide similar health benefits. While meeting the guidelines is likely to yield optimal health benefits, there is value and health gain in physical activity, even when below the moderate intensity and 150 minute thresholds.

Adults should also undertake physical activity to improve muscle strength on at least 2 days a week.

Long periods of sitting should be broken up with some light activity.

Children Aged 5-18 years

Ensuring that all children are as active as possible throughout childhood is important for population health.

- engage in moderate to vigorous intensity physical activity for at least 60 minutes and up to several hours every day
- incorporate vigorous intensity activity, including those that strengthen muscle and bone strength on at least 3 days a week
- minimise the amount of time spent being sedentary (sitting) for extended periods.

This activity can include all forms of active play such as physical education, active travel, activity after-school, play and sports. There are separate guidelines for the under 5s, including those capable of walking.

Older adults aged 65+ years

In terms of volume and duration, the guidance is similar to that of adults aged 19-64 years. Activity should add up to at least 150 minutes (2 ½ hours) a week of moderate intensity activity.

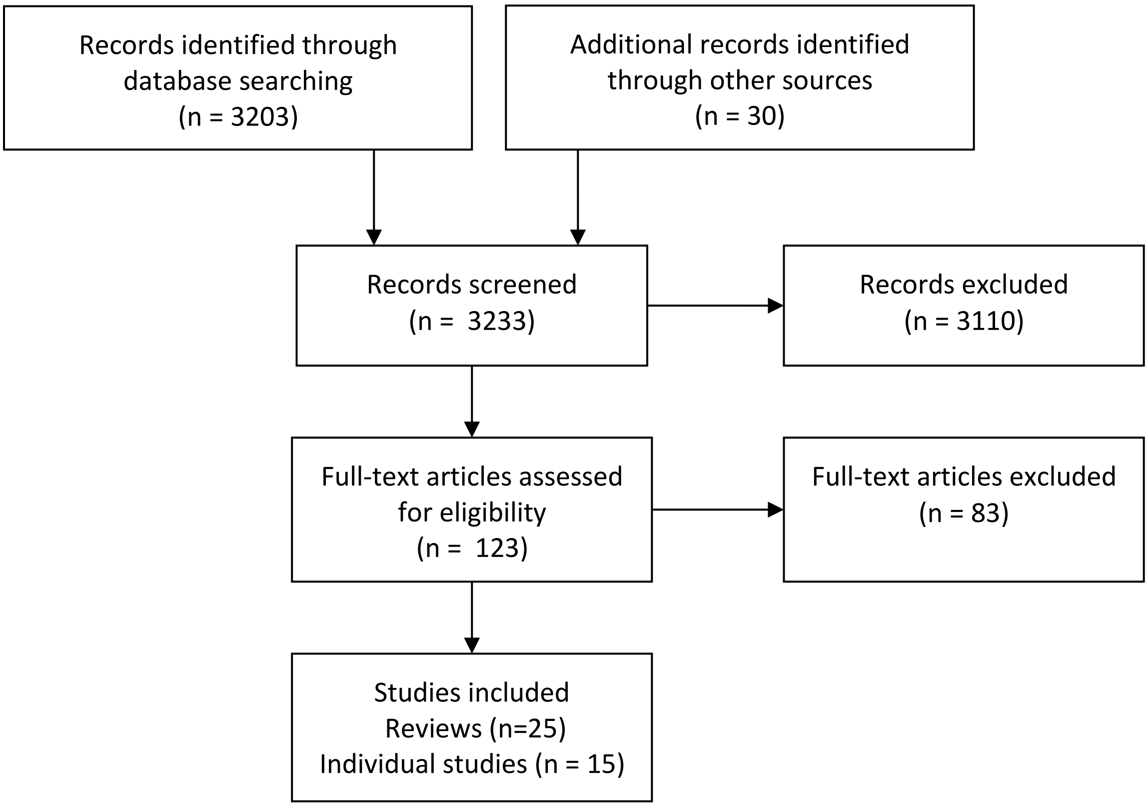
Resistance training for major muscle groups is recommended on at least 2 days per week. Balance and flexibility training is also relevant in this group, aiding independence and functional outcomes.

Increasing volume and frequency of light activities and reducing sedentary behaviour are a place to start for the frailer or disabled older adult. Both strategies contribute towards improving health.

Appendix 2: Search Terms

Outcomes	Search terms
Walking, cycling and active travel terms	bicylc*, active commut*, active travel*, walk*
Physical health outcomes	All-cause mortality, morality, cardiovascular disease, coronary heart disease, cancer*, type II diabetes, glucose metabolism, diabet*, cardiorespiratory fitness , aerobic capacity, blood pressure, hyperten*, vascular function, endothelial function, arterial stiffness, blood lipids, cholesterol, haemostat*, inflammatory markers, body composition, body weight, obes*, musculoskeletal.
Mental health outcomes	Depress*, anxiety, panic disorder*, self-concept, , psychological stress, psychological discomfort, psychological distress, psychological well-being, subjective well-being, psychological resilience, resilien*, social isolation, loneliness, social support.

Appendix 3: Study flow diagram



Appendix 4: Mental health outcome definitions, see Kelly et al 2018 [8]

Table 1 Mental health outcomes included in this review

Outcome	Description
Depression	Depression is a mood disorder categorised by prolonged periods of low mood, or lack of interest and/or pleasure in normal activities most of the time. Depression includes dysthymia and major depressive disorder.[88]
Anxiety	Anxiety is characterised by uncomfortable or upsetting thoughts, and is usually accompanied by agitation, feelings of tension and activation of the autonomic nervous system. It is important to note the distinction between transient anxiety symptoms (state anxiety), persistent symptoms (trait anxiety) and anxiety disorders: a collection of disabling conditions characterised by excessive, chronic anxiety. Examples of anxiety disorders are specific phobias, social phobia, generalised anxiety disorder, panic disorder, obsessive-compulsive disorder and post-traumatic stress disorder.[4]
Self-esteem	Self-esteem is the feelings of value and worth that a person has for oneself. It contributes to overall self-concept as a construct of mental health.[89]
Psychological stress	Psychological stress or distress can be defined as the unique discomforting, emotional state experienced by an individual in response to a specific stressor or demand that results in harm, either temporary or permanent, to that person.[90]
Psychological well-being	Psychological well-being links with autonomy, environmental mastery, personal growth, positive relations with others, purpose in life and self-acceptance. This is often referred to as eudemonic well-being.[10]
Subjective well-being	Subjective well-being is defined as a person's cognitive and affective evaluations of his or her life. Often referred to as hedonic well-being (and closely aligned with the construct of happiness).[11]
Resilience	Resilience refers to a steady trajectory of healthy functioning after a highly adverse event or a conscious effort to continue in an insightful and integrated positive manner as a result of lessons learnt from an adverse experience.[91]
Social isolation and loneliness	Social isolation is described as lack of a social network while loneliness is described as an unfulfilled social need.[92]