**Rapid international evidence
review: Impact of the COVID-19
disease control measures on
physical activity and dietary
behaviours and weight**

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Executive summary

This review aims to summarise recent international evidence on the implications of COVID-19 disease control measures for people's diet and physical activity behaviours and weight. This is to understand the potential indirect health impacts of these measures and identify gaps in the evidence to direct further research. Findings from this review will inform the development of public health policy in light of the COVID-19 outbreak.

The review was conducted by researchers from Public Health Scotland and the Scottish Government. It draws on evidence from 22 articles published between December 2019 and June 2020, which were identified as relevant to the research questions.

Limitations of the evidence base

There are some significant limitations to the retrieved evidence summarised below. In light of these limitations the findings should be interpreted with caution.

- The review draws on evidence from international studies, with only one study using a UK population sample. The nature, extent, timing and duration of restrictions vary substantially across the different countries studied which prevents comparisons being made across study findings.
- The vast majority of the retrieved studies use self-reported data. The inability to blind participants to the exposure of lockdown, combined with the absence of control groups, means there is significant potential for biases to shape the observed findings. The results may be particularly susceptible to recall issues and demand characteristics (for example, participants may respond in a manner that they perceive is socially desirable or expected of them in the context of the pandemic).
- Many of the retrieved articles rely on convenience samples of the wider population, with few attempting to establish or verify population

representativeness. Many of the samples are extremely under-representative of males, limiting conclusions that can be made about this population.

- Participation in online surveys during lockdown requires the individual's ability and inclination to take part, as well as the necessary electronic devices. Certain employment sectors may be under/over represented, given the designation of some individuals as 'key workers'. As such, socioeconomic representativeness of the retrieved studies is uncertain.
- A further limitation is that many of the retrieved studies focus on the early stages of lockdown, therefore, it is not possible to use the retrieved literature to comment on longer-term changes as lockdown episodes have progressed and gradually lifted.

Key findings

Impact of COVID-19 disease control measures on physical activity behaviours

- Overall, the retrieved literature is reasonably consistent in identifying widespread, but not ubiquitous, deterioration in physical activity levels.
- Among cross-sectional studies of general population samples, the proportion self-reporting increases, decreases or no change in physical activity are approximately equal (thirds).^{1,2,3,4,5,6,7} The relative proportions across these studies appear to be sensitive to the precise nature of physical activity asked about (changes in the type or intensity of physical activity appear to be less commonly reported).
- Studies allowing quantitative assessment of changes in physical activity generally suggest that the overall trend among general population samples is of reducing physical activity duration and/or intensity (around 30% reductions during lockdown compared to pre-lockdown).^{8,9,10}
- The retrieved longitudinal studies are limited in that they tend to be conducted among smaller, and less generalisable samples, but these also tend, on average, to find evidence of decreasing physical activity and increasing

sedentary behaviour (though substantial variation is observed in the apparent degree of change).^{7,11,12,13,14}

- Step-count data offer the most objective assessment of changes in physical activity levels and corroborate the observed decreases in self-reported walking activity. The data also reflect international differences in the timing and stringency of lockdown measures.¹⁵

Impact of COVID-19 disease control measures on dietary behaviours and intake

- Among studies that asked participants to self-report direction of change, the majority report stability in dietary behaviours and intake during lockdown.^{1,4,7,9,16,17}
- However, there appears to be a sizable group who perceive to have increased overall food intake throughout lockdown. The proportion ranged from 30% to 53%.^{4,8,17,18,19}
- Quantifiable estimates suggest that energy intake increased between 10% and 20% for some groups during the lockdown period.^{7,13}
- A sizeable proportion also report increased snacking behaviour. Estimates show, on average, little change in fruit and vegetable consumption and a tendency towards increased consumption of discretionary foods.^{7,8,9,16,17,18,20}

Impact of COVID-19 disease control measures on weight outcomes

- Across several different study designs, the majority of people perceive or self-report relative stability in weight during lockdown.^{4,7,9,17,18,20}
- However, both weight gain and loss were observed among a sizeable minority, with a greater proportion tending to report weight gain.^{7,18,20}
- In studies measuring perceived weight change, there was also a sizeable proportion (30%–40%) who reported not knowing what had happened to their weight.^{4,17}

- Where self-reported measurements were provided, the studies indicate for those who gained weight that there was an approximate average weight gain of 2 kg, equivalent to a change of 0.73 body mass index (BMI) units for an individual 1.65 m tall.^{7,18,20}
- A single study of a population of obese adults in the USA found that the majority (70%) felt the disease control measures had made it harder to achieve their weight-loss goals.²¹

Differential impacts across population groups

A subset of the retrieved studies formally examine associations between outcomes and behaviour, and individuals' characteristics. A number of the retrieved articles analyse a large set of characteristics potentially associated with changes in weight or related outcomes, but without appropriate statistical adjustment. This increases the risk of finding significant associations by chance, therefore, the summary below focuses on associations which were observed independently across multiple studies.

- There is some evidence that for those with a higher BMI at the beginning of the COVID-19 lockdown, there is a greater likelihood of an increase in dietary intake and deterioration of dietary behaviours.^{7,9,18} There is some, albeit weaker, evidence of greater likelihood of reduced physical activity levels and/or intensity among these individuals.^{1,5}
- From a small number of studies there is an indication that people in lower socioeconomic groups are more likely to report more negative impacts on their physical activity and dietary behaviours.^{2,4,5}
- People of working age appear to be more likely to report change (increase or decrease) in physical activity than older adults,^{2,5} and younger people are more likely to report deterioration in dietary quality.^{7,9}

The majority of studies are heavily skewed on the basis of sex towards female participants, meaning the representativeness of male participants is poor. However, some indications of differential impact by sex are worth noting for further exploration.

- Overall, the evidence tends to indicate greater declines in physical activity among males, particularly in more intensive forms of exercise.^{10,13}
- Deterioration in dietary quality during lockdown appears to be more common among females, in particular increases in consumption of foods high in fat, sugar or salt.^{1,9,13,19}
- Mirroring sex differences in dietary changes, females were observed in two studies to be at greater risk of weight gain.^{7,9}

Discussion

In light of the limitations of the retrieved evidence, it is not possible to draw firm conclusions. However, overall, the retrieved research suggests that, within the observed populations, for many there has been no perceived change in their physical activity, dietary behaviours or weight during the COVID-19 disease control measures. There is, however, some indication of at least a short-term decline in physical activity and dietary quality for a sizable proportion of the observed populations. There is some indication that these negative impacts may be more likely among those who were at risk of poorer outcomes prior to the COVID-19 outbreak, particularly for those who were originally overweight, suggesting a potential widening of health inequalities.

Implications for Scotland

Owing to the limitations of the retrieved evidence and lack of research available from the UK or Scotland at this stage, the application of the findings here are limited in relation to the general population of Scotland. However, the evidence in this review from other, largely comparable, Western populations provides some indication of the potential impacts that we should be alert to.

Research to track changes in physical activity, diet and weight as COVID-19 control measures ease in the form of high-quality, longitudinal studies within the Scottish population using validated tools would be important to inform the development and

targeting of policy in light of the COVID-19 outbreak. It is key that these studies are representative with respect to demographic characteristics.

Data generated through these studies should also be considered together with other data sources such as industry sales data, use of leisure facilities and referrals to weight-management services to generate a wider understanding of the longer-term impacts of the restrictions on individuals and services.

The evidence in this review suggests that lockdown measures do not affect populations uniformly, therefore, it will be important to explore both the overall trends in the Scottish population, and the impacts seen in subgroups of the Scottish population, for example disadvantaged socioeconomic groups, children and young people, ethnic minorities and people living with obesity.

As mentioned previously it will also be important to understand why individuals' behaviours have changed both positively and negatively, to shape policy responses. Therefore, good-quality qualitative studies exploring in-depth why behaviours have changed particularly in vulnerable groups will be important.

Background

As a result of the significant health threat posed by the COVID-19 outbreak, countries across the world are implementing unprecedented disease control measures in an effort to restrict the spread of the virus. The nature, extent, timing and duration of these restrictions varied substantially across different countries, ranging from policed restrictions on all but essential movement (for example, in Italy and Spain) to more voluntary restrictions on social distancing (for example, in Sweden). These measures all served to limit the time people spent in close contact with other people outside of their household group, in closed hospitality venues such as bars and restaurants and limited opportunities for physical activity through closure of leisure and sports facilities. Details of Scotland's disease control measures are provided in **Appendix 1**.

There is a developing body of evidence which suggests an association between higher body mass index (BMI) and COVID-19 severity and mortality.²² In Scotland the majority of the adult population is either overweight or obese (66%), with 32% of children at risk of being so.²³ As it is likely we will be living with the virus for some time, there is potential for reinstatement of restrictions at local or national levels. As such, there is a short-term need to understand whether disease control measures have exacerbated obesity levels and potential COVID-19 severity, through impacting linked behaviours such as physical activity, dietary intake and sedentary behaviour. Further, the implications of these behaviours and obesity for non-communicable diseases are cumulative. It is therefore also important to understand the medium and long-term implications of lockdown measures, such as those caused by short-term or longer-lasting changes to obesity-related behaviours.

Research questions

This review aims to answer the following research questions:

- 1 What impact are COVID-19 disease control measures having on physical activity behaviours?
- 2 What impact are COVID-19 disease control measures having on dietary behaviours and intake?
- 3 What impact are COVID-19 disease control measures having on weight?
- 4 Are differential impacts of COVID-19 disease control measures seen across population groups?
- 5 What are the key learnings and implications for Scotland?

Methodology

A search strategy (**Appendix 2**) was developed to identify studies published between 1 December 2019 and 30 June 2020 in the MedRxiv and Proquest databases. This strategy was also used to search the Evidence for Policy and Practice Information (EPPI) COVID-19: A living systematic map of the evidence.²⁴ This comprises studies on COVID-19, identified in MEDLINE and Embase, which were published since 2019, updated weekly.

Titles and abstracts were screened by a single reviewer, and the following inclusion criteria applied:

- Primary study or systematic review.
- Written in English language.
- Studies conducted with populations in Western Europe, Australia, Canada, New Zealand or the USA.
- Studies of general populations.
- Related to COVID-19 disease control measures and diet, and physical activity behaviours and/or weight.

Critical appraisal of the included studies was conducted by a single reviewer using the appraisal tool for cross-sectional studies (AXIS).²⁵ In addition to collecting information pertinent to critical appraisals, data were extracted from the articles by a single reviewer including information on population characteristics, the nature of measures used to assess behaviour or weight change, key findings and factors associated with change in behaviours and outcomes.

Results

This search strategy identified 590 articles for screening after duplicates were removed (see Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram in **Appendix 3**). A total of 22 articles were assessed as directly relevant to the above research questions. Thirteen of these report studies were conducted with European populations (predominantly Italian; four studies) including one conducted in the UK. Five studies were conducted in North America (one in Canada, four in the USA) and two in Australia. The remaining two studies were conducted with international samples.*

The vast majority of the retrieved articles report cross-sectional study designs (15/22), using convenience samples of the general adult population (median sample size = 1,491, range from 123 to 13,515). Seven studies collected data at more than one time point, however, these tended to report data from smaller and therefore less generalisable samples (median sample size = 237, range from 41 to 37,252).†

There are some significant limitations to the retrieved evidence summarised here, and this is discussed in detail in the limitations section at the end of this review.

From the retrieved research there is only one study conducted in the UK, which limits the application of the findings in relation to the general population of Scotland. In addition, the retrieved studies focus on the early stages of lockdown, therefore it is

* NB these international studies do not exclusively report on data collected within countries that are within the scope of this review).

† Excluding two 'big data' studies that use large volumes of smartphone step-count or GPS data.

not possible to use the retrieved literature to comment on longer-term impacts as lockdown restrictions have changed.

There is a lack of objectively measured data in the retrieved studies – the vast majority using self-reported data. The inability to blind participants to the exposure of lockdown, combined with the absence of control groups, mean there is significant potential for biases to shape the observed findings.

In addition, the reliance on convenience samples of the wider population and majority of studies using online surveys is likely to result in certain groups being under and over represented, which limits the generalisability of the findings to the general population.

Impact of COVID-19 disease control measures on physical activity behaviours

Of the 22 articles identified, 16^{1-15, 21} aimed to identify the impact of COVID-19 disease control measures on physical activity. Of these studies, only one was conducted within the UK.

Cross-sectional studies

Self-reported direction of change in physical activity

Eleven^{1-10,21} of the retrieved articles document cross-sectional studies of changes in physical activity levels. Among these, the most common approach was to ask a sample of the general population to self-report simply whether their physical activity had increased, decreased or stayed the same during lockdown. Across all the seven studies,¹⁻⁷ at least 20% of participants were reporting no change in physical activity. Similarly, across these studies it is typical for around one third to report an increase in physical activity, with approximately one third reporting a decrease.

Some exceptions to this general observation are noteworthy. Two studies^{1,5} find higher proportions of participants reporting no change in physical activity, which appears to reflect differences in the nature of the questions posed to participants. Whereas the majority of studies ask a simple overarching question about change in

physical activity in general, Bhutani et al¹ asked separately about changes in walking, sitting, and moderate and vigorous physical activity. In this sample of 1,609 adults in the USA, 50% report no change in moderate physical activity and 46% report no change in vigorous activity. The proportion of participants in Bhutani et al's study reporting no change in walking or sitting activity is closer to the overall levels of stability in levels of physical activity observed in most other studies (36%). This may reflect that in the other studies this is what participants tend to think about when asked to reflect on physical activity.

Rogers et al⁵ found that 63% of a sample of 5,820 UK adults reported not changing the intensity of their exercise (and only 12% report increasing). These estimates may reflect that participants were asked to report changes in the nature of exercise that they regularly participated in before and during lockdown (with response options 'none', 'mild', 'moderate' and 'vigorous'). This measure may be less susceptible to change than frequency or duration, particularly as the range of activities available to do was limited as the settings in which individuals may adopt a new physical activity (for example, an introductory class in a gym) have also been affected by lockdown. This may also reflect that individuals have identified means of carrying out their usual forms of exercise at home (for example, improvising with weights, running or cycling outside), to mitigate against facilities being closed. Additionally, as this study was conducted fairly early on in the UK's period of lockdown (6–22 April), it may be the case that individuals anticipated a relatively short lockdown episode and hence still considered themselves to still engage 'regularly' in their usual forms of exercise despite facilities being closed.

Larger proportions reporting decreases in physical activity were also observed in three studies. One study⁴ found that 60% of a sample of 7,514 adults in Spain report decreasing their level of physical activity, the second⁷ observed 53% of a sample of 37,252 adults in France to self-report a decrease and the third⁶ observed that 49% of an Australian sample of 1,491 adults reported doing less physical activity during lockdown.

Only two of the retrieved studies measured self-reported change in sedentary behaviour. Bhutani et al¹ found that 58% of their USA sample reported increasing sitting time, with only 6% reporting a decrease. Similarly, Deschasaux-Tanguy et al⁷ found that 63% report increasing the amount of time spent seated or lying down.

One study²¹ investigated the impact of disease control measures on the physical activity of a clinical sample of 123 patients in the USA with obesity (mean BMI 40 kg m²). Patients were asked to compare a range of exercise behaviours pre- and during lockdown. Around half (48%) reported decreasing the duration of exercise, with 56% reporting a decrease in the intensity.

Quantifiable self-reported physical activity changes

Methods of estimating quantifiable change in physical activity in the retrieved cross-sectional studies include comparing participants' retrospective quantitative estimation of pre-lockdown activity against that of their activity during lockdown, allowing insight into the amount of change. It should be noted that these studies are also self-reported and so subject to the same self-reporting bias and inaccurate recall as those mentioned above.

One study⁸ asked a sample of 1,047 participants worldwide to record the frequency and duration of walking, moderate and vigorous physical activity, once to retrospectively report typical activity before lockdown and again to reflect activity during lockdown. These estimates were used to calculate a combined weekly metabolic equivalent, which is an overall measure of the intensity of an individual's physical activity. Sitting duration before and during lockdown was also recorded. This study found, on average, that both the reported frequency and duration of all forms of physical activity were significantly lower during lockdown compared to before. The magnitude of these changes ranged between a 23% and 35% reduction. For instance, while this sample reported engaging in an average of 108 minutes per week of any form of physical activity before lockdown, this reduced to 72 minutes per week during lockdown (a reduction of 34%). Slightly higher proportionate reductions were observed in calculated metabolic equivalents (between 35% and 38%), which reflects the relative weighting of physical activity and duration in the calculation of

these estimates. Conversely, participants in this sample report having increased their sitting time from 5 hours a day to 8 hours (an increase of 29%). It should be noted that only 21% of the participants in this study were residents in Europe. As the results are not disaggregated by geography, it is difficult to extrapolate the findings of this particular study to the Scottish context.

Another study¹⁰ conducted a similar analysis using a sample of 2,524 people in Italy. On average a 35% reduction in total physical activity in metabolic equivalents was seen. For this sample, the greatest proportional reduction was seen for walking activity, where participants reported a 61% reduction, compared to only a 6% reduction in weekly moderate exercise, defined as equivalent to cycling at a regular pace or gardening.

A third study⁹ assessed the frequency and type of physical activity before versus during lockdown among 3,533 people in Italy. This study found no significant change in the proportion of individuals that reported doing no physical activity (including walking) before (38%), versus during (37%) the lockdown. However, the authors also observed an apparent shift in frequency among those who did report physical activity. The percentage of people reporting some form of physical activity five or more times a week increased from 6% before lockdown to 16% during lockdown. The reverse pattern was seen among those reporting some form of physical activity one or two times a week (reducing from 28% to 21%).

Longitudinal studies

Six studies^{7,11-15} present data collected at more than one time point, allowing for changes over time in physical activity to be investigated (typically contrasting pre- and peri-lockdown).

Pre-post longitudinal studies

The majority of the retrieved longitudinal studies^{7,11-14} are non-experimental pre-post studies in which baseline self-reported data on a pre-existing cohort of subjects were collected before disease control measures, with follow-up measures taken opportunistically during lockdown (typically via an online survey).

It should be noted that two of these articles^{11,12} appear to base their analyses on the same population of participants, which could artificially inflate the apparent abundance and consistency of this body of evidence.[‡] These studies yield almost identical findings relating to change in physical activity, therefore are presented together here. Baseline measurements of physical activity were conducted in September/October 2019 as part of a pre-existing longitudinal study examining self-reported factors influencing physical activity and substance misuse. The authors enquired about the frequency of a range of physical activities over the past week for this baseline assessment, then again during COVID-19 lockdown in early April 2020 (approximately three weeks into Croatia's lockdown). Comparing these two measurements, these studies both observed a small but statistically significant decrease in physical activity of around 11%.

A further study¹³ used a sample of 149 undergraduate students in Australia who recorded their duration and intensity of physical activity as part of their tuition at three timepoints in late March/early April 2018, 2019 and 2020 (approximately two weeks since the transition to online learning on the campus). Combining the two first measurements to act as a baseline, significant reductions in both walking participation and duration were observed. No difference was seen in a binary measure of engagement in (or abstinence from) vigorous activity. However, among males participating in this type of activity, less active time was reported in 2020 versus 2019 (60 minutes less per week) and 2018 (150 minutes less per week).

Supplementing their data on self-perceived changes in physical activity, Deschasaux-Tanguy et al⁷ also presented quantitative estimates of physical activity intensity and duration, comparing April 2019 to April 2020 as part of an existing longitudinal study of adults in France. Among those reporting a decrease in physical activity (N = 16,471), a 37% reduction in metabolic equivalents was seen when comparing pre- and peri-lockdown estimates. Conversely, among those reporting an increase in activity (N = 5,648), an 18% increase in metabolic equivalents was

[‡] It appears that the 388 adolescents in Croatia analysed in Sekulic et al, 2020¹² also form part of the sample of 823 adolescents in Zenic et al, 2020.¹¹

observed. A slight decrease of 6% was observed among those reporting no change to their activity (N = 7,122). An increase in quantitatively calculated sedentary activity was observed for all participants regardless of their perceived direction of change in physical activity, however, this increase was larger among those reporting to have decreased physical activity (18% increase) compared to those who reported no change, or increased activity (10% and 8% increases, respectively).

A further study¹⁴ used a sample of 41 parents of children and adolescents in Italy with obesity (aged 6–18 years), who reported the duration of both sports activity and screen time at a baseline measurement between May and July 2019 and then again three weeks into lockdown (April 2020).[§] Within this sample, a significant decrease in sport activity duration was observed from 3.6 to 1.3 hours per week (a decrease of 64%). Conversely, a significant increase in screen time (a proxy of sedentary behaviour) was seen from 2.8 to 7.6 hours per day (a 171% increase).

Region-level accelerometer data

One further study¹⁵ used a large worldwide (187 countries) data set of daily step-count measurements based on smartphone accelerometer data, spanning a period prior to and during lockdown measures (19 January 2020 to 1 June 2020). The subjects of this study constitute 455,404 users of a specific smartphone application, with over 19 million individual daily step-count measurements. This implies an average of around 42 daily counts per individual, however, these data are presented as country-level and city-level daily step-count averages, rather than being used to investigate change in physical activity within specific individuals over the measurement period. It should also be noted that there are likely to be systematic differences in the characteristics of those who own and carry a smartphone, for example by age and socioeconomic status, and therefore is not necessarily representative of the general population. This study found evidence that within 30 days of the World Health Organization's (WHO) declaration of a pandemic (11 March 2020), an overall 27% decrease in average step count was observed

[§] This follow-up measure used a slightly adapted questionnaire to reflect closure of sports and exercise facilities, with any type of physical activity included in this latter assessment.

versus the period immediately before (19 January to 11 March). Likely reflecting national differences in the severity and timing of the COVID-19 outbreak and subsequent lockdown measures, significant international differences were seen in the observed change in average daily step count, ranging from a maximum decrease of 7% in Sweden (which had comparatively lenient lockdown measures) to 49% in Italy (which had stricter restrictions). This study is only able to analyse one particular type (and intensity level) of exercise. It is not possible, therefore, to generalise the results of this study to other types of activity.

Impact of COVID-19 disease control measures on dietary behaviours and intake

Of the 22 articles identified, 14^{1,4,7-9,13,14,16-21,26} reported findings on the impact of COVID-19 control measures on dietary intake. None of the study populations included Scotland or the wider UK.

Cross-sectional studies

Self-reported direction of change in dietary behaviours

Eleven cross-sectional studies^{1,4,7-9,16-21} looked at dietary behaviours and intake.

Within these studies, the most common approach was to ask a sample of the general population to self-report whether a range of dietary behaviours and dietary intakes had increased, decreased or stayed the same during lockdown measures.

One study⁸ asked a sample of 1,047 participants worldwide to report their dietary behaviours before and during the lockdown. Findings indicate that the proportion reporting consumption of unhealthy foods either 'most of the time' or 'always' was significantly higher during lockdown (34% vs 25% before lockdown). Perceptions of eating being 'out of control' were also found to be significantly higher during lockdown (30% vs 12% before lockdown). Additionally, greater proportions reported a higher number of main meals consumed per day during the lockdown period (15% vs 7% for four main meals, 6% vs 2% for five main meals and 3% vs 1% for more than five main meals). The number of snacks consumed between meals, including late-night snacking, also increased significantly (40% vs 20% before lockdown). It is

important to note that only 21% of the participants in this study were residents in Europe while the majority of participants lived in Africa (40%) and Asia (36%).

One study¹⁹ of 1,404 adults in Portugal asked participants if they were engaging in certain dietary behaviours more than usual. Results indicate some evidence of altered eating habits, with a large percentage of participants reporting that they started to eat more often than usual (45%) and in larger quantities than usual (32%) during lockdown. However, it is important to note that eating more or more frequently does not necessarily constitute deterioration or improvement in diet as the nature of the consumed foods was not recorded in this study.

A study¹ asked a sample of 1,609 adults in the USA to self-report dietary intake of specific food groups during lockdown. Findings show that across all observed food groups prepared at home, the majority of participants (at least 52%) report stability in their consumption; vegetables 65% (19% increase and 16% decrease), fruits 61% (21% increase and 18% decrease), sugar-sweetened beverages 72% (16% increase and 12% decrease), diet drinks 74% (12% increase and 14% decrease), processed foods 56% (32% increase and 12% decrease), ultra-processed foods 60% (25% increase and 15% decrease) and savoury snacks (such as crisps) 52% (36% increase and 12% decrease). For takeout or fast food the majority (59%) reported a decrease in consumption (12% increase and 29% stable intake).

A study⁹ used a sample of 3,533 adults in Italy to assess the impact of lockdown on a range of eating habits. Around half of the participants reported a change in their hunger/satiety perception; 18% reported that they had less appetite while 34% reported an increased appetite. Just over half of the participants reported no change in their number of daily meals (59%) while 18% declared skipping meals and 24% introduced an additional snack or a main meal. Participants' reflections on changes in the consumption of specific food groups were also reported. Findings showed that the majority of participants (> 50%) reported similar consumption of most food categories before and during lockdown. Similar numbers of participants reported eating more or eating less healthy food (fruit, vegetables, nuts and legumes) during lockdown (37.4% and 35.8%, respectively). The largest proportion reporting

increases in consumption were observed for homemade desserts (around two fifths of participants reporting an increased intake), homemade pizza (around a third reporting an increase), cereals (around a quarter) and hot beverages (around a quarter). The most common decreases were observed for fresh fish (around a quarter reporting a decrease), delivery food (around a fifth) and packaged baked products and desserts (around a fifth).

The dietary habits of 7,514 adults in Spain were examined in one study.⁴ The majority (64%) reported that, overall, they were not eating more during lockdown, with around a third (36%) reporting an increase. Furthermore, just under half (47%) reported snacking at similar levels to before lockdown with just over a third (38%) reporting an increase in snacking. Around three quarters (73%) reported eating similar levels of fried foods as before lockdown while 20% reported eating less. Frequency of home cooking increased during lockdown with 46% reporting cooking more while just 4% reported cooking less. The study also assessed adherence to the Mediterranean diet.^{**} Adherence was scored on a points-based system ranging from 0 to 14. Results indicate a slight, but statistically significant, increase in adherence to the Mediterranean diet with the mean score rising from 6.5 before lockdown to 7.3 during lockdown measures, suggesting an improvement in dietary quality.

Another study of 600 adults in Spain¹⁶ showed that the majority of participants (> 50%) reported similar consumption of most food categories before and during lockdown, but at least 30% reporting either increases or decreases across certain categories. The food least likely to be stable include sweets, where 50% reported eating more, and fish where over 30% reported eating less. Around one third (35%) reported an increase in consumption of meat, fruits and bread, and around 40% reported an increase in pasta and rice consumption. Findings also showed the different diet-related habits that participants reported they would like to maintain after lockdown measures were lifted. Almost a quarter (23%) reported an intention to keep

^{**} A Mediterranean diet is defined as a healthy nutritional pattern characterised by high fruit and vegetable consumption, legumes, nuts, grains, fish and unsaturated fats such as olive oil.

cooking, 16% keeping different 'healthy' eating habits, 9% baking, 9% eating fruit/vegetables and 8% planning grocery shopping and meals.

In one study,⁷ a sample of 37,252 adults in France provided 24-hour dietary records and reported self-perceived dietary quality during lockdown. The majority (75%) of participants perceived that their overall diet quality had not changed; however, 56% reported modifying eating practices, including 48% reporting cooking at home more frequently, 40% no longer eating out and 21% reporting having trouble sticking to a mealtime schedule. Only 11% reported that their diet was of lower quality and 14% reported that their diet was of better quality compared to pre-lockdown. On snacking, the majority reported no change (70%) while 21% reported increasing snacking and 9% reported reduced snacking. Participants' perceived change in consumption of specific foods was variable, with between 2% and 22% reporting increases in certain items. The most frequently perceived increases were for sweets and chocolate (22%), biscuits and cakes (20%), and tea (19%). Between 1% and 31% reported decreasing the consumption of specific items, with decreases most frequently observed for fresh fish (31%), red meat (22%) and sandwiches/pizza/pies (17%). These perceived changes were corroborated by quantitative data from the 24-hour dietary records.

One study¹⁷ reported findings on the dietary habits of a sample of 1,932 adults in Italy who self-reported consumption of food groups both before and during lockdown. Findings showed that nearly half (47%) of participants did not report eating more during the lockdown. However, around half also reported that they are overall eating 'a bit more' or 'much more' (46% and 7%, respectively). Reasonably large proportions of the sample reported changes in consumption of specific food groups. The biggest increases were for chocolate, ice cream and desserts, with 43% of the sample reporting eating more of these foods (and only 14% reporting a decrease). A large increase was also observed for coffee, tea/infusions, with 30% of participants reporting an increase (and 12% reporting a decrease). Additionally, almost a quarter (24%) reported an increase in sweet/salty snacks, with 19% reporting a decrease. The biggest decrease was seen for ready meals, with half of the sample (50%)

reporting a decrease and only 3% reporting an increase. This change may reflect the increase in time that participants had to cook throughout lockdown. Sugary drinks showed the second biggest decrease (22%) with only 5% reporting an increase. The majority of the sample reported eating 'more or less the usual amount' of fruit and vegetables (69%) while 21% reported increasing their intake. Reasons for decreasing fruit and vegetable consumption were given with 56% selecting 'I feel less like eating them'. Around a third said they were 'having a harder time finding them' (34%) and a further 10% said 'the price has increased too much for me'.

Changes in consumption of various other food groups were also reported. Consumption of red meat and processed meat remained broadly stable for the majority, with 10% reporting an increase and 15% reporting a decrease. This was similar for fresh or canned fish, with 9% reporting an increase and 14% reporting a decrease. For milk/yogurt and cheese, the majority reported no change in consumption (14% and 13% increase and 9% and 8% reporting a decrease, respectively). The vast majority (92%) reported no change in olive oil consumption with 6% reporting an increase and 2% reporting a decrease. Finally, around two thirds (66%) reported no change in consumption of biscuits with 19% reporting an increase and 15% reporting a decrease.

A further study²⁰ reported findings on a range of dietary intake behaviours in a sample of 173 adults in the USA. Participants were asked to report changes in factors that contribute to changes in eating through the Weight and Lifestyle Inventory (WALI). The largest change was observed for eating because of cravings, with 73% reporting at least a small increase of this behaviour. At least half of the sample reported an increase in the following behaviours: eating when bored (73%), snacking after dinner (65%), eating in response to sight/smell of food (65%), eating with family and friends (59%), eating when stressed (52%) and eating when depressed/upset (50%). It is important to note, however, that the questionnaire items in this study did not allow for participants reporting decreases in these behaviours.

A cross-sectional study¹⁸ looked at the dietary habits of a sample of 1,097 adults in Poland who were not working during lockdown. Around half (52%) of the sample

reported snacking more during lockdown and 44% reported eating more. A total of 62% reported an increase in cooking. It is important to note that this sample contained a particularly high proportion of female participants (95%), which limits the ability to extrapolate these findings to the wider population of adults out of employment during lockdown.

Another cross-sectional study²¹ used a sample of 123 adults in the USA living with obesity to explore the health implications of COVID-19 stay-at-home orders. A total of 61% reported that they found healthy eating challenging with the same percentage reporting stress eating. Almost two thirds (64%) reported cooking more often during lockdown.

From this evidence there appears to be some significant but variable changes in dietary behaviours across the studies examining change in dietary behaviours. This variation may be culturally mediated and dependent on the specific disease control measures in force.

Longitudinal studies

Four longitudinal studies^{7,14,13,26} observed the impact of COVID-19 disease control measures on dietary behaviours and intake.

Ashby²⁶ examined the impact of COVID-19 on visitation to fast food establishments in the USA. The study presents an opportunistic use of smartphone data using anonymised GPS data, accounting for roughly 10% of smartphone devices in the USA, at 138,989 fast food establishments from 1 December 2019 through to 30 April 2020. It is important to note that it is not clear how the GPS data have been used to infer visits to fast food establishments, therefore the validity of this measure is uncertain. Further, this methodology does not provide insight into the quantity or quality of purchases within these outlets. Findings showed that visits to fast food establishments fell significantly in March when stay-at-home orders were in place. In April, a steady resumption of visitation to these establishments occurred and this rebound occurred faster in counties with the highest percentage of adult populations with obesity.

Deschasaux-Tanguy et al⁷ studied a sample of 37,252 adults in France who provided 24-hour dietary records every six months as part of an existing longitudinal study and again during lockdown (April–May 2020). Results show that almost a quarter (23%) of participants increased their energy intake by more than 10% during lockdown. However, 33% of participants decreased their energy intake by more than 10%.

A study¹³ used a sample of 149 undergraduate students in Australia who recorded 24-hour dietary recalls at three time points in 2018, 2019 and during lockdown in April 2020. The first two measurements were combined as a baseline. Findings were different for males and females. No difference was seen in the total energy intake for males, however, for females, total energy intake was 20% higher. Furthermore, for males no difference was found in the number of snack occasions, energy intake attributed to snacks or the energy density of snacks consumed. For females, an increase in daily snack occasions was observed with an increase to an average of two daily snack occasions in 2020 compared with one in 2018/19. Total energy intake increased by 50% and energy density of snack foods increased by 62%.

A further longitudinal study¹⁴ of a sample of 41 children and adolescents with obesity in Italy reported findings on dietary intakes during lockdown. Dietary behaviours were collected at baseline (May–July 2019) and three weeks into the national lockdown (approximately one year later). Findings showed that there were no changes in reported vegetable intake and that fruit intake increased slightly. Consumption of potato chips, red meat and sugary drinks increased significantly. Dietary intake was provided by parents' responses and the authors themselves note that there is a possibility that the parent's sense of their child's behaviour was heightened during lockdown, potentially inadvertently biasing their responses. It is also unclear whether the increase is a result of lockdown restrictions or a secular increase over time due to the long time lag between baseline and lockdown data collection.

Impact of COVID-19 disease control measures on weight outcomes

Of the 22 articles identified, six studies^{4,7,9,17,18,20} reported findings on the impact of COVID-19 control measures on weight. None of the study populations included Scotland or the wider UK.

Cross-sectional studies

Self-reported direction of change in weight

Three cross-sectional studies recorded perceived changes in weight in the general population. Two of these studies^{4,17} asked the sample to self-report perceptions on whether their weight had increased or remained stable and one⁹ also allowed self-reporting of perceived weight loss.

Across the two studies^{4,17} that recorded only perceived weight gain, most thought their weight had remained stable (around 50%), a large proportion (up to 40%) did not know, and a minority (between 13% or 20%) perceived that they had gained weight over the lockdown restrictions.

Di Renzo⁹ reported perceived changes in weight gain or weight loss. The study found 8% of the sample population of 3,533 adults in Italy felt they had 'gained a lot' of weight, 40% felt they had slight weight gain, 37% felt their weight had remained stable and 14% felt they had lost weight.

Self-reported impact on weight-loss goals

One study²¹ investigated the impact of the disease control measures on the weight-loss goals of a sample of 123 patients in the USA with obesity (mean BMI 40 kg/m²). Patients were asked to report their perceptions of how lockdown measures had impacted them on achieving their weight-loss goals. The study found that most (70%) reported lockdown had made it harder to achieve their weight-loss goals, 22% reported it had had no effect in achieving their weight-loss goals and 8% reported the lockdown restrictions had made it easier.

Quantifiable self-reported change in weight

Two studies included self-reported quantifiable changes in weight. Across the two studies that asked participants to weigh themselves,^{18,20} the percentage that reported weight gain was 22% and 30%, respectively. Sidor⁸ measured weight at four to six weeks into lockdown, and calculated a mean weight gain of 2 kg for the 30% that had gained weight. Zachary et al²⁰ did not calculate mean weight gain, but 22% of the sample reported gaining between 2 kg and 5 kg. The authors did not report at what point into lockdown the weight measure was taken.

A smaller proportion (around 20%) in both studies reported weight loss. Sidor et al¹⁸ calculated mean weight loss to be 2 kg for the 20% who had lost weight. In the Zachary et al²⁰ study 15% of the sample lost between 2 kg and 5 kg and a small minority (4%) reported losing more than 5 kg. As in the previous studies, the proportion of the population who reported that their weight had remained stable was approximately half in both studies.

Longitudinal studies

One study⁷ asked participants to provide a record of their weight at the beginning of lockdown and at week eight of lockdown restrictions. Analysis of the data from 22,042 adults in France found that 35% of the sample population gained weight between the two time points, with a mean weight gain of 1.8 kg (standard deviation 1.3), and 23% of the sample population reported weight loss, with a mean weight loss of -2 kg (standard deviation 1.4). Weight remained stable for 42% of the participants.

Differential impacts across population groups

The identified literature highlights that the implications of COVID-19 disease control measures on weight outcomes and related behaviours are not uniform or universal. Rather, across demographic and personal characteristics there appears to be variation in whether changes are observed, and in their apparent degree and direction. A subset of the retrieved studies formally examine associations between

outcomes and behaviour, and individuals' characteristics. These studies are summarised below.

Baseline weight status

Overall, there is some indication that deleterious changes are more likely to be observed and are of a greater magnitude among those with a higher BMI pre-lockdown. For instance, there is some (albeit weak) evidence that overweight and obesity is associated with changes in physical activity, with increased weight being associated with a lower likelihood of increasing moderate forms of exercise,¹ or adopting more intensive exercise during lockdown.⁵ There is stronger evidence that deterioration in diet during lockdown is more common among those already overweight, with positive associations observed between weight status and increased snacking and intake of discretionary foods.^{7,9,18}

Baseline physical activity

There is mixed evidence with respect to baseline engagement in physical activity. For instance, studies^{11,12} find that changes in Croatian adolescents' physical activity are positively correlated with some, but not all, collected measures of aerobic fitness collected some months before lockdown. Similarly, one study³ finds that a group of adults in Canada defined as 'more active' on the basis of pre-lockdown exercise levels (greater than 150 mins per week moderate to vigorous activity) are more likely to have increased physical activity during lockdown (41% of those classified as 'inactive' became less active during lockdown compared to only 22% of those classified as 'more active'). Contrary to these findings, a study of adults in Italy¹⁰ found that those categorised as having low physical activity expenditure before lockdown, experienced an overall increase in expenditure, whereas the converse was true for those classified as highly or moderately active before COVID-19. This may reflect 'regression to the mean' type and/or reporting artefacts whereby daily exercise encouraged during lockdown increases the reported energy expenditure of those who typically do little physical activity, but closure of leisure facilities may have functioned to reduce physical activity duration and intensity among those who were originally more active.

Sex

Participant sex represents the characteristic that is most frequently subjected to formal analysis as a risk or protective factor for the reported changes in diet and physical activity. It should be noted that there was a heavy bias towards females in the sample populations, limiting the representativeness of males where formal analysis takes place.

Overall, it is slightly more common to observe greater declines in physical activity among males, with deterioration in diet appearing to be more common among females. There is some indication that the greater decline in physical activity among males predominantly reflects changes in more intensive forms of exercise. For instance, one study¹³ demonstrated little sex difference for milder forms of physical activity (for example, walking) among undergraduates in Australia; however, a significantly greater decrease in more vigorous forms was seen for males. A further study¹⁰ also reported that adult males in Italy showed a larger decline in metabolic equivalent energy expenditure than females. While the above findings have been interpreted by some authors as reflecting males' disproportionate reliance on leisure facilities and organised team sports,¹³ evidence from the UK directly contradicts this hypothesis. Rogers et al⁵ found, conversely, that being female was associated with an increased likelihood of reporting a reduction in physical activity intensity versus that observed for males. Constandt et al² also found no significant effect of sex when examining perceived changes in physical activity.

Evidence of greater deterioration of females' dietary intake was reasonably consistent with a larger proportion of females reporting eating greater amounts and more frequently during lockdown.^{1, 9, 13, 19} There is some evidence¹ that sex differences in dietary intake changes are particularly large for processed foods, desserts and chocolate where females were more likely to report an increase (for example, 24% of males reported an increase in the consumption of processed foods compared to 38% of females).

Fewer studies examine changes in perceived weight by sex, however, two of the retrieved studies indicated a positive association between weight gain, perceived or

measured,^{7, 9} and being female. Owing to the self-reported nature of the studies it is possible that cultural norms which result in females being more 'weight conscious' may result in the strength of this association being inflated.

Age

Overall there is some evidence of both positive and negative changes in obesity-related behaviours among younger individuals, which may reflect that disruption of daily routines is more common and more impactful among this group (particularly when comparing working-age participants with non-working-age individuals). For instance, one study² found that participants aged 18–34 years and 35–54 years were more likely to report an increase in physical activity compared to 55–74-year-olds. Another study⁵ also found evidence that younger participants (20–34 years) were more likely to report either a reduction or an increase in physical activity intensity versus those aged over 70. For dietary behaviours, while there is also evidence of greater variability for younger people, the general trend was for deterioration in diet for these individuals. For example a study⁹ found that lower age was associated with an increase in junk food consumption (packaged sweets and baked products, sweet beverages, savoury snacks and dressing sauces). Furthermore, a second study⁷ found those who reported increasing snacking were more likely to be under 50 years old. Similarly, a third study⁴ found a higher adherence to the Mediterranean diet for those aged 51 years and older before lockdown and lower odds of change to adherence to the Mediterranean diet throughout lockdown.

Socioeconomic status

It was not common for the retrieved studies to formally examine the association between socioeconomic status and change in obesity or related behaviours. However, the studies that do provide insight into this factor give evidence that more deprived individuals have disproportionately increased their risk of non-communicable disease outcomes. One study² found that those with high school education only are more likely to report a decrease in physical activity than those with a higher education level. Similarly, a second study⁵ found (when controlling for

age, sex, household income and pre-existing conditions) that those with a higher education degree were less likely to report a decrease in physical activity intensity than those with only a high school education. For dietary intake and behaviours, one study⁴ found that those with a higher education level had a greater likelihood of increasing their adherence to the Mediterranean diet during lockdown. However, another study⁷ found contradictory evidence, observing an increase in snacking to be associated with having a higher degree of education.

Location

One longitudinal study¹¹ explicitly aimed to examine the differential impact of lockdown measures on physical activity among urban and rural adolescents in Croatia. While in the overall sample of 823 a significant decrease in physical activity levels was observed during lockdown, this effect appeared to be driven by those living in an urban environment, with no significant change being observed for those living in rural areas.

Discussion

The retrieved evidence has significant limitations, largely due to the reliance on self-reported measures and other methodological biases as discussed in the limitations section of this review. This literature, therefore, does not allow firm conclusions to be drawn; however, overall the retrieved research suggests that within the observed populations for many there has been no perceived change in their physical activity, dietary behaviours or weight during the COVID-19 disease control measures. There is, however, some indication of at least a short-term decline in physical activity, and dietary quality for a sizable proportion of the observed populations. The evidence suggests that these negative changes tend to be more likely among those who were at risk of poorer outcomes prior to the COVID-19 outbreak, particularly for those who were originally overweight. This suggests a potential widening of health inequalities in this respect.

Although the methodology used in most of the retrieved studies limits our ability to make causal inferences, a small subset of the retrieved evidence is better suited to making the determination that national lockdown measures precipitated the observed changes (rather than merely coinciding with them). This is particularly the case for physical activity, where objective data in the form of repeated step-count measurements coincide with the timing, duration and stringency of lockdown measures in multiple independent international samples.¹⁵

Within the retrieved studies there was limited exploration of participants' rationalisation of why obesity and related behaviours may have changed during COVID-19 disease control measures. One exception to this is a study¹⁷ which identified low mood, perceived access and affordability as factors limiting the consumption of fruit and vegetables. For policy-makers it will be important to understand the reasons for changes in behaviour, including any positive changes, to respond to these as restrictions ease or are reintroduced.

Implications for Scotland

Owing to the limitations of the retrieved evidence and a lack of research available from the UK or Scotland at this stage it is not possible to comment definitively on the impact of COVID-19 control measures on physical activity, diet and weight in the general population of Scotland. However, the evidence in this review from other, largely comparable, Western populations provides some indication of the potential impacts that we should be alert to.

Quantitative evidence on changes in weight during lockdown is sparse, and limited to self-reported data, but points to relatively minor increases where these are seen. This may indicate that lockdown measures have not necessarily exacerbated the obesity challenges already faced in Scotland, however, if sustained over a longer period these increases are likely to have a greater impact.

Owing to the retrieved research being undertaken largely during early stages of lockdown in some countries, we are unable to make any comment about how long any observed changes in obesity-related behaviours may persist, or how they may vary over time. Further research to continue to track changes in physical activity, diet and weight as COVID-19 control measures ease, in the form of high-quality, longitudinal studies within the Scottish population, will be important to inform the development and targeting of policy in light of the COVID-19 outbreak.

It is key that these studies are representative with respect to demographic characteristics, particularly age, socioeconomic status and sex (sex is especially poorly represented in the retrieved international literature). Efforts should be made to triangulate methods of data collection, including objective measures, and telephone and in-person interviewing, as appropriate to the disease control measures at the time, to reduce potential bias generated by solely self-reported, online data collection.

Data generated through these studies should also be considered together with other data sources such as industry sales data, use of leisure facilities and referrals to

weight management services to generate a wider understanding of the longer-term impacts of the restrictions on individuals and services.

The evidence in this review suggests that lockdown measures do not affect populations uniformly. Therefore, it will be important to explore both the overall trends in the Scottish population, and the impacts seen in subgroups of the Scottish population (for example, disadvantaged socioeconomic groups, children and young people, ethnic minorities and people living with obesity).

As mentioned previously, it will also be important to understand why individuals' behaviours have changed, both positively and negatively, to shape policy responses. Therefore, good-quality qualitative studies exploring in-depth why behaviours have changed, particularly in vulnerable groups, will be important.

Limitations of the evidence base

A major methodological weakness of the retrieved literature is that researchers have been unable to blind participants to the exposure in question. Participants may be inclined to respond in a particular way to adhere to what they understand the researchers' motives to be, or what constitutes a socially desirable response.

The majority of studies were cross-sectional in design and required participants to retrospectively report pre-COVID behaviours and reflect on their perception of change during lockdown. This may introduce a source of bias reflecting differential accuracy of pre- and peri-lockdown estimates. For example, participants may reflect on 'typical levels' from the time of year or on the period of time immediately before lockdown.

It is also likely, particularly for weight, that participants may not be able to reliably or accurately perceive changes within the time period involved. For example, the studies which quantifiably measured weight estimate a 2 kg mean weight change (for illustration this represents a change in BMI equivalent to 0.73 kg/m² for an individual 1.65 m tall). A study that explored the levels at which people can perceive a change

in weight in human faces²⁷ found that even under ideal conditions people may only be able to perceive changes in weight above 1.33 kg/m².

The included studies which were longitudinal in design tended to include data from substantially fewer participants (with a number focusing on specific samples that are less generalisable, for example among a clinically obese sample^{14,26}). This means we can be less certain about the precision of estimates and of any extrapolation made to a wider population.

A further limitation of longitudinal studies is that owing to the nature of the COVID-19 pandemic, data collection pre- and peri-lockdown had to be undertaken in different environments (typically in-person then online, respectively). It is potentially the case that factors affecting the validity of participant reports, including demand characteristics, vary according to the setting of data collection.²⁸

The measures used in the identified studies to record changes in behaviours and outcomes often had not been formally developed, or had internal and external validity examined. Further, some of the included studies are likely to have heavily biased the responses due to phrasing or restrictions on the options available to participants. For example, allowing participants to report change in unhealthy behaviours but not healthier ones.²⁰

Objective measures are less susceptible to the measurement issues described above, however, only one study using such methods was identified by the present review. Tison¹⁵ used smartphone-based accelerometer data. Limitations of this study include likely bias in the samples obtained from each region as inclusion requires smartphone access and consistent carrying behaviour. These criteria are likely to vary systematically by certain factors (especially age and socioeconomic status).

In addition, surveys were conducted at different times and in countries with different COVID-19 restrictions and therefore limited how the studies can be compared. It should also be recognised that some of the apparent differences between studies in terms of the demographic might be confounded by the differences in lockdown measures and the time periods the participants were asked about.

Some studies^{1,5,7,13} have not undergone a peer-review process (pre-print), meaning their methodology and interpretation has not been appraised by a group of impartial researchers before being appraised by the authors of this review.

The quality appraisal exercise found a number of methodological and reporting weaknesses in the identified articles, some of which likely represent a trade-off between timeliness and rigour. For instance, it was very rare for the samples in the retrieved articles to be based on a priori sample size calculations (two exceptions were Almondoz et al²¹ and Zachary et al²⁰). This means that the studies may not have sufficient statistical power to detect existing associations. Furthermore, while the retrieved studies typically articulate their target population(s) well, there is little formal evidence of the obtained samples being representative of these populations. This is particularly the case among general population samples which, for example, are heavily skewed on the basis of sex towards female participants. Obtained samples are also likely to be skewed on the basis of socioeconomic status and employment status/sector, as participation in most of the retrieved studies requires access to digital hardware, in addition to the spare capacity and desire to take part. These factors are unlikely to be distributed equally across socioeconomic groups.

A further limitation of the retrieved evidence base is that authors of the retrieved articles typically fail to adjust statistical tests for multiple comparisons. At a significance level of 5%, one in every 20 statistical tests or comparisons that are made will be significant purely by chance. This may mean that some of the identified associations are spurious, therefore, increased confidence should only be placed in those associations that are found across multiple independent samples.

Limitations of this review

The databases searched for this review were limited to MedRxiv Proquest databases and the Evidence for Policy and Practice Information (EPPI) COVID-19: living systematic map of the evidence,²⁴ and it is therefore possible that articles have been published that have not been identified in our review. We only considered articles up to 30 June 2020 and, given the rapid development of research in this area, it is therefore likely that further research will have been published which is pertinent to

the research questions in this review. We also only included English-language articles which may mean relevant studies published in other languages are not captured here. For pragmatic reasons, to conduct the rapid review, it was necessary to undertake single-reviewer screening, quality appraisal and data extraction. This may limit the accuracy with which relevant articles have been identified and appraised.

Appendix 1: Scotland's COVID-19 disease control measures

Scotland's first²⁴ case of COVID-19 was confirmed on 1 March 2020, with the first death coming on 13 March. Scotland's lockdown initially coincided with the UK Government's restrictions on population movement, with people being requested from 23 March onwards to work at home if at all possible and to leave the house only to obtain food or medicine, or for one form of exercise per day. Sit-in, out-of-home food venues were closed, however, many businesses moved to a takeaway model during this period. In Scotland, easing of these restrictions followed a published route map²⁹ outlining transition out of lockdown in phases, beginning on 28 May. While many of the lockdown restrictions had been eased at the time of writing, there are lasting changes to population movement, with individuals remaining advised to work from home wherever possible. Indoor leisure facilities also closed for five months, only reopening with significant restrictions on access. Stricter local lockdowns have also been applied following isolated outbreaks (for example, in Aberdeen City). From 14 September restrictions were retightened across the UK to limit the size of gatherings to no more than six.

Appendix 2: Search strategy

Search number 1 (physical activity)

(ab(coronavirus OR sars-cov-2 OR covid-19 OR covid19) AND ab("Physical Activity" OR "physical activities" OR exercise* OR exercising OR "indoor exercise" OR "outdoor exercise" OR sedentary OR cycling OR walking OR running OR "online exercise class" OR "at home workout" OR "virtual studio" OR "living room workout" OR "free workout" OR sport*)) OR (ti(coronavirus OR sars-cov-2 OR covid-19 OR covid19) AND ti("Physical Activity" OR "physical activities" OR exercise* OR exercising OR "indoor exercise" OR "outdoor exercise" OR sedentary OR cycling OR walking OR running OR "online exercise class" OR "at home workout" OR "virtual studio" OR "living room workout" OR "free workout" OR sport*))

Search number 2: (diet, weight, etc.)

(ab(coronavirus OR sars-cov-2 OR covid-19 OR covid19) AND ab(Diet* OR Nutrition* OR Food* OR Drink* OR Eat* OR Consum* OR HFSS OR snack* OR Fruit* OR Vegetable* OR "Sugar sweetened beverage" OR SSB OR Caloric OR Calorie OR Meal* OR Confectionary OR takeaway OR sweet* OR salt OR BMI OR weight OR "body mass index" OR adiposity)) OR (ti(coronavirus OR sars-cov-2 OR covid-19 OR covid19) AND ti(Diet* OR Nutrition* OR Food* OR Drink* OR Eat* OR Consum* OR HFSS OR snack* OR Fruit* OR Vegetable* OR "Sugar sweetened beverage" OR SSB OR Caloric OR Calorie OR Meal* OR Confectionary OR takeaway OR sweet* OR salt OR BMI OR weight OR "body mass index" OR adiposity))

Appendix 3: PRISMA diagram

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