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Defining and measuring long COVID fatigue: a scoping review

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ABSTRACT

Objective Long COVID encompasses a range of symptoms in which fatigue is one of the most prevalents. It is clear from other conditions that the definition and measurement of fatigue can be complex, but it is not clear how fatigue is defined and measured in long COVID. To advance our understanding, this review summarises the definitions and measures of long COVID fatigue being used by researchers.

Design Scoping review following JBI methodology and reports using the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping reviews.

Data sources Medline, Scopus, CINAHL, PsycINFO, EMCARE, Web of Science, Epistemonikos, Cochrane Central Register of Controlled Trials, Dimensions, Overton and ProQuest Dissertation & Theses Database were searched from January 2020 to May 2023.

Eligibility criteria This review included quantitative and qualitative studies that included any definition of long COVID and/or measurement tool that purported to quantify either the impact, severity or symptoms of long COVID fatigue.

Data extraction and synthesis Two independent reviewers screened the title, abstracts and full texts of the selected studies based on the inclusion criteria. Data extraction was performed by two independent reviewers. The data were summarised in tabular format and a narrative summary.

Results The search retrieved 9839 studies, of which 57 met the inclusion criteria. Only 21 (37%) provided a definition of fatigue. Definitions ranged across physical, mental, cognitive, emotional, psychosocial, central, peripheral, postexertional symptom exacerbation and general dimensions of fatigue. Fifty-five (96%) used a measurement or assessment of fatigue. Twenty-six measures of fatigue were identified: 21 self-report measures (eg, Fatigue Assessment Scale) and five fatigability measures that purport to reflect changes in physiological processes that contribute to or reflect fatigue (eg, change in force generating capacity of a muscle).

Conclusions The definitions identified demonstrate considerable diversity, each highlighting different dimensions of long COVID fatigue. Long COVID fatigue was predominantly measured through self-report methods, which were problematic. There is an urgent need to better understand long COVID fatigue and to identify the different mechanisms involved. In order to do this, we need consistency with the language around fatigue and its measurement within research and across disciplines.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This review will be the first to identify and summarise the definitions and measures of long COVID fatigue being used by researchers reported as per the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols extension for scoping review guidelines.
⇒ A thorough literature search of 11 databases was conducted to ensure that all relevant studies were identified. This included specialised databases that could have unique references where the topic of fatigue may be represented.
⇒ The decision to limit the search to English-language publications was made due to practical considerations, such as resource limitations for translating non-English studies. Therefore, only English language publications were included in the final analysis, possibly limiting conclusions as definitions and measures in different languages could have been omitted.

Review registration The protocol has been registered on open science framework (https://doi.org/10.17605/OSF.IO/HNF8Z).

INTRODUCTION

Long COVID is a multisystem condition in which individuals exhibit persistent symptoms lasting over 12 weeks that emerge during or after SARS-CoV-2 infection.[1] Long COVID has emerged as a substantial global health concern.[2] Over 17 million individuals in the WHO European region experienced long COVID between 2020 and 2021,[3] while in the UK, an estimated 1.9 million reported symptoms as of March 2023.[4] The condition has profound ramifications, encompassing increased healthcare utilisation[5] and workforce attrition, with approximately 80 000 individuals withdrawing from employment since the pandemic's onset.[6]

Fatigue has emerged as a prevalent and debilitating symptom of long COVID, significantly affecting functioning.[7–10] Although the term fatigue is common parlance, a formal and widely accepted definition is elusive.

There is debate around whether fatigue should be considered as an experience of symptoms evaluated through self-report,[11 12] and as performance decline independent of the perception of fatigue.[13] Performance decline (fatigability) reflects the extent or speed of change relative to a reference value during a specified duration of task performance or measure of mechanical output.[14] This review adopts that fatigue is only symptom experience measured through self-report, and any other measure is considered fatigability.[15]

Within these models of fatigue, a multidimensional approach is evident. A dimension is a specific aspect along which fatigue can vary. Billones *et al*[16] identified eight dimensions of fatigue in the definitions and measures of fatigue used across non-oncologic medical conditions (physical, cognitive, mental, motivational, emotional, peripheral, central, psychosocial). These appear to capture elements of perceived fatigue and performance decline as well as potential physiologic processes that can contribute to both.

Current treatment guidelines for long COVID fatigue focus on managing symptoms.[17] Ongoing research is investigating the underlying mechanisms of long COVID fatigue to address the root cause and enable more targeted interventions.[18–20] Valid and reliable measures of fatigue and fatigability are critical to the informed design and evaluation of any intervention.[18] The first step in developing and selecting measurement tools is defining the construct to be measured.[21] Uncertainty regarding the definition and measures of long COVID fatigue will hamper information synthesis, impede comprehension of the symptom and ultimately halt the development of targeted interventions.

A clear definition of long COVID fatigue is lacking, and it is not clear which dimensions of fatigue, if any, are considered and captured in this condition. This review will identify the definitions of fatigue used in long COVID research, and the dimensions of fatigue and fatigability they consider.

METHODS

This scoping review followed the JBI methodology[22] and reports using the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping reviews (figure 1).[23] The protocol has been published[24] and registered on the open science framework.[25] In this scoping review, a deviation from the protocol occurred as we utilised the OVID EMCARE database instead of Embase.

Medline (OVID), Scopus, CINAHL (EBSCO), PsycINFO, Web of Science, Epistemonikos, Ovid EMCARE and Cochrane Central Register of Controlled Trials, Dimensions, Overton and ProQuest Dissertation & Theses Database were searched from January 2020 to May 2023. The search strategy identified quantitative and qualitative studies that included (a) any definition of long COVID fatigue and/or (b) an assessment or measurement tool that purported to quantify either the impact, severity or symptoms of long COVID fatigue in adults. The full search strategy can be found in online supplemental material 1.

Search results were collated and deduplicated in Endnote V.20 (Clarivate Analytics, Pennsylvania) by BT. Remaining studies were uploaded to Rayyan for screening. Two independent reviewers screened the title, abstracts and full texts of the selected studies based on the inclusion criteria (as described above). One reviewer (BT) screened 100% of the studies, with a second reviewer (DE, BJ, CD, HL) each independently screening 25% each of the studies. Any disagreements were resolved through discussion or with a third reviewer (JD, CB, RP).

A custom form was developed for data extraction, which was piloted on a random sample of 10 included studies and modified based on feedback. One reviewer (BT) performed data extraction on 100% of the studies with a second reviewer (DE, BJ, CD, HL) each independently performing a second data extraction on 25% of studies.

The data are presented in tabular format to present the concepts that are being explored in this review. Tables are used to present general characteristics of the included studies, the definitions of fatigue, and measures and assessment tools (including the name of the measure, the construct measured, whether the measure is validated and how it is scored or quantified). The tables are accompanied by a narrative summary to uncover patterns of definitions and measures, allowing us to derive new insights and understanding from the data.

Patient and public involvement statement

Patient and public involvement (PPI) partners have been involved since the beginning of the PhD project, contributing to discussions based on their experiences of long COVID. It became clear that participants describe their fatigue in different ways and experience a range of symptoms including both physical, social and cognitive fatigue. This led the research team to consider the importance of identifying studies on long COVID that capture these different aspects of fatigue.

The PPI partners have played an active role in developing ideas and methods for a separate empirical study on long COVID fatigue, which has been the primary focus of PPI discussions. However, these conversations also helped shape the concept for this scoping review.

Although the PPI partners were not directly involved in planning or writing this specific manuscript, they have contributed to the overall PhD project, particularly in shaping the long COVID fatigue research, an area of great interest to both patients and the public.

RESULTS

The search retrieved 9389 studies. After deduplication, 4663 study's title and abstracts were screened, of which 96 were eligible for full-text screening (figure 1). Thirty-nine studies were excluded after full-text screening (online

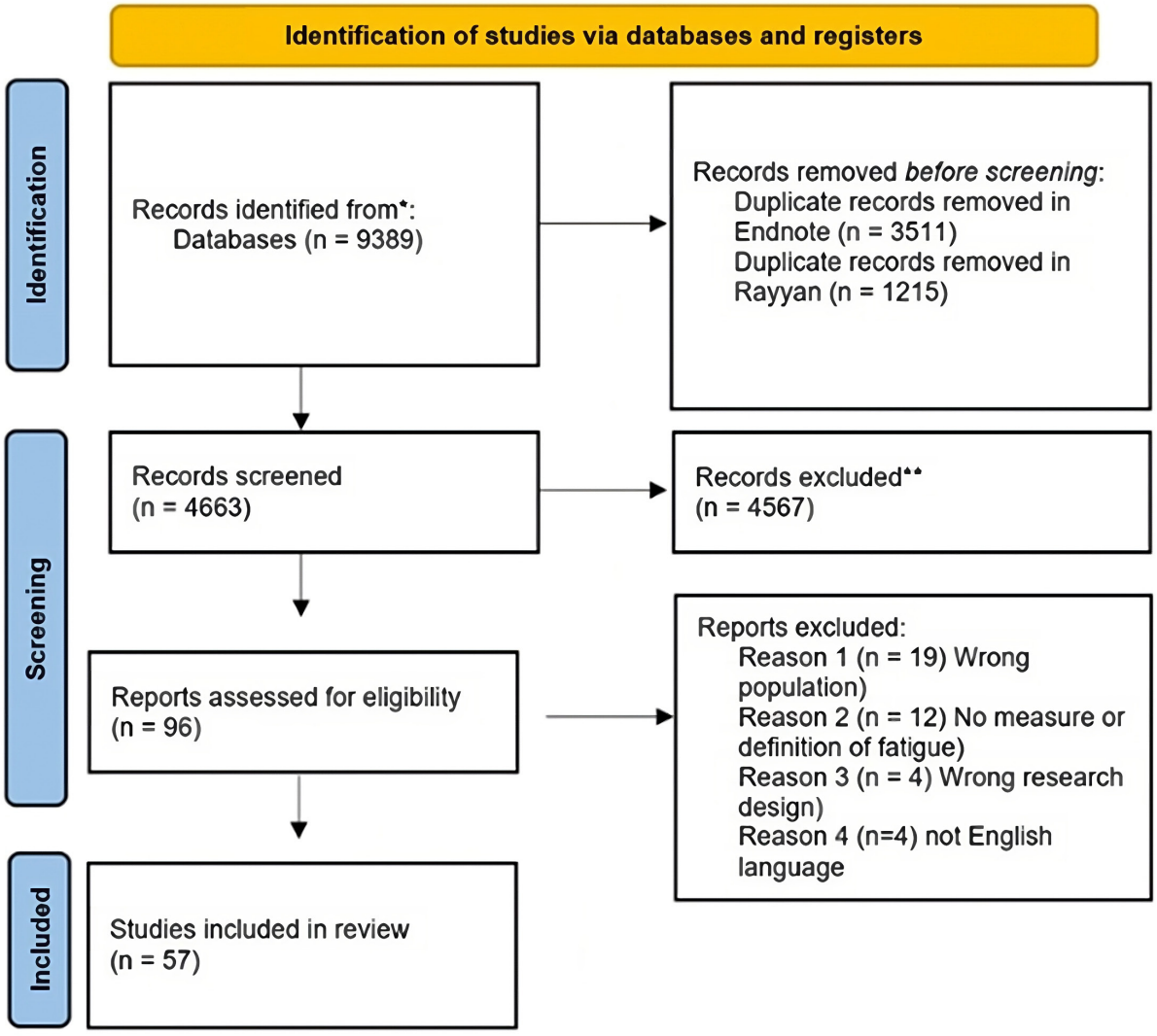

Figure 1 PRISMA-ScR for flow of studies across the review. Flow diagram indicates the number of sources of evidence screened, assessed for eligibility and included in the review, with reasons for exclusions at each stage. PRISMA-ScR, Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping reviews.

supplemental material 2). Fifty-seven studies met the eligibility criteria and were included in the review.

Characteristics of the included studies are summarised in table 1 (further details are provided in online supplemental material 3). All studies were published between 2021 and 2023. Eleven different study designs were used, the most common were cross-sectional (n=21), randomised controlled trial (n=9) and cohort (n=9). A total of 9964 participants were included across the studies (mean=175, range=10–1414) and the majority of participants were women (61%). Across the studies, participants included those with a mix of mild and severe acute COVID-19 (n=28),[8 26–52] only mild acute COVID-19 (n=11),[53–63] severe acute COVID-19 (n=8)[64–70] and the remaining studies did not provide the information.

Studies spanned 22 countries: Italy (n=8),[27 44 54 60 67 71–73] Spain (n=6),[30 39 43 57 59 65] United Kingdom (n=7),[31 48 53 56 61 74 75] USA (n=6),[32 35 36 52 76 77] Germany (n=5),[28 38 50 63 78] Ireland (n=3),[8 47 62] the Netherlands (n=3),[51 68 72] two from Denmark,[26 41] Egypt,[66 79] Brazil,[45 55] Hungary[40 80] and one from France,[64] India,[37 81] Canada,[9] Poland,[69] Iraq,[70] Switzerland,[34] Chile,[33] Austria,[42] Israel,[58] Turkey[29] and Japan.[49]

There are multiple definitions of long COVID, not all studies used one consistently. Fifty-six studies provided a definition of long COVID (see online supplemental material 4), adopting the WHO (n=9), National Institute for Health and Care Excellence (n=17), or the Centers for Disease Control and Prevention (CDC) (n=4) definition. Two studies stated they followed the WHO definition, and two the CDC definition, but presented modified versions. Twenty two developed their own definition of long COVID.

Definitions of long COVID fatigue

Only 21 of the 57 studies (37%) provided a definition of fatigue (table 2). These definitions have been mapped

Table 1 Summary of characteristics of included studies

Characteristics	Number (%) reference
Study method	
Quantitative	53 (93)[8 9 26–28 30 33–45 47 49 51–69 71–81 85 86]
Qualitative	3 (5),[29 31 32]
Mixed methods	1 (2),[48]
Study type	
Randomised controlled trial	9 (16)[37 43 45 66 69 71 77 79 81]
Non-randomised controlled trial	3 (5)[27 64 76]
Cohort study	8 (14)[28 36 40 42 51 70 72 86]
Case–control study	1 (2)[58]
Cross-sectional study	21 (37)[8 9 26 30 35 39 41 47 52 53 55–57 59–63 65 67 73]
Retrospective study	3 (5)[34 75 80]
Case series	2 (4)[49 74]
Prospective study	2 (4)[33 38]
Longitudinal study	5 (9)[31 44 54 68 78]
Descriptive phenomenological study	1 (2)[29]
Exploratory study	1 (2)[32]
Before and after design	1 (2)[48]
Year	
2021	13 (23)[9 29 33 40 44 47 51 57 62 67 73 75 81]
2022	28 (49)[8 27 28 30–32 34 36 39 41 42 46 48 50 55 58 60 61 63–66 69 72 74 76–78]
2023	16 (28)[26 35 37 38 43 45 49 52–54 56 59 68 70 79 80]

to categories based on the terms provided within them, following the framework proposed by Billones *et al*,[16] which includes physical, cognitive and mental. Due to the use of novel terms in the reviewed definitions, two additional categories have been included: postexertional symptom exacerbation (PESE) and psychological fatigue. Post-PESE, which encompasses postexertional malaise, is used in X of the included studies to refer to an exacerbation of multiple symptoms due to exertion. Although PESE involves a worsening of multiple symptoms, the worsening of fatigue is typically a core component,[82] making it essential for understanding the complexity of fatigue in long COVID. From the 19 studies that provided a definition of fatigue, two studies included and summarised their participants' definitions of fatigue rather than developing their own definition of fatigue.

The 20 most common words used in the definitions are presented in figure 2. The top 10 included were physical (n=25), cognitive (n=16), mental (n=14), COVID (n=13), tiredness (n=9), feeling (n=9), exertion (n=8), central (n=7) and exhaustion (n=7).

Measures of long COVID fatigue

Of the 57 included studies, 55 employed at least one measure of fatigue. Of these, 55 (100%) used a self-report measure (online supplemental material 5) and four (7%) also used fatigability (non-self-report) measures of physiological processes or task performance (see table 3).

Self-report measures

Across the 55 studies using self-report measures, there were 20 validated measures of fatigue, two validated measures of other constructs (long COVID symptoms, depressive symptoms) and two non-validated measures developed for the purpose of the study. The most frequently used validated measures were the Chalder Fatigue Questionnaire (CFQ, 14/55 studies), the Fatigue Severity Scale (FSS, 11/55 studies) and the Fatigue Assessment Scale (FAS, 9/55 studies). From the validated measures of fatigue, various types of self-report measures were identified: generic (designed to be used across conditions) (11/20 studies) and disease-specific (developed specifically for use with patients with a certain condition) (9/20); evaluative (designed to measure the severity of symptoms) (20/20) and discriminative (designed to differentiate fatigued from non-fatigued individuals) (2/20). From all of the measures used across the studies, both unidimensional (13/24) and multidimensional scales (11/24) were identified. Unidimensional measures provide a singular score for overall fatigue, whereas multidimensional measures present information on more than one dimension of fatigue, for example, physical, cognitive or mental, allowing for the calculation of both subscale and global scores. The self-report measures used by studies and their adherence to the original measures are presented in online supplemental material 5.

Measures of fatigability

Five fatigability (non-self-report) measures were utilised across the 57 studies (see table 3), each aimed at quantifying a change in task performance. None of the five studies quantified if their measure of fatigability was associated with any self-reported measure of fatigue.

Measuring dimensions of long COVID fatigue

Physical fatigue

Physical fatigue was the most assessed dimension in 29/57 studies. Nineteen studies used a validated, multidimensional measure that provided a subscore of physical fatigue. The most common were the CFQ (14/29 studies) and the Modified Fatigue Impact Scale (MFIS, 4/29 studies). Nine studies utilised the FAS unidimensional measure, which considers physical fatigue, but only provides a composite score of fatigue. One study used an unvalidated measure in which questions related to physical fatigue were taken from the Checklist of Individual Strength (CIS) fatigue subscale.

Cognitive fatigue

Cognitive fatigue was assessed in 12/57 (21%) studies. All used a multidimensional measure that included a

Table 2 Definitions of long COVID fatigue

Definition quote. [reference, page number]	Dimension
"Fatigue appears to be a multi-system pathology associated with immunological, metabolic, and hormonal anomalies … [It involves] feelings of weakness, with physical and cognitive actions being more effortful. Such effects could result from changes at many levels of the nervous system; here we focused on five potential neural substrates of fatigue, that might not only result in increased performance fatigue but also increased perception of fatigue"[53, p2].	Physical Cognitive Central
"Fatigue is a subjectively perceived exhaustion that follows disproportionately after exertion and does not improve adequately after sleep or rest (post-exertional malaise, post exertional malaise)"[28, p1]	PESE
"Fatigue is defined as a general feeling of weakness or an unpleasant subjective feeling that can progress from a lack of energy to a feeling of burnout … post-COVID-19 fatigue was defined as the reduction in physical and/or mental performance that occurs from alterations in central, psychological, or peripheral factors because of the COVID-19…. Fatigue is a multidimensional symptom based on subjective perceptions."[29, p2].	General Physical Mental Central Psychological Peripheral
"Defined broadly, fatigue is characterized by excessive tiredness, physical and/or cognitive, and muscular weakness… the distinct manifestations of fatigue depends on the underlying disease as well as sociodemographic variables. …. The term 'cognitive fatigue' is commonly used to define a condition in which there is impaired performance during tasks requiring a sustained mental effort"[30, p391]	Physical Cognitive Peripheral
"Brain fog defined as 'neurocognitive symptoms' to describe subjective problems 'to do with the ability to think and reason, [including] the ability to concentrate, remember things, process information, learn, speak, and understand'"[31, p.2] Summary of participants' definitions—"Prominent fatiguability and interaction between perceptually cognitive or physical symptoms combined with the impact on professional and personal activities, functional ability, and identities to produce a destabilising, debilitating, frustrating, stigmatising, and frightening situation"[31, p6] "Participants described having distinct experiences of 'neurocognitive' compared with 'physical' symptoms. The latter were generally presented as somatic manifestations, often familiar from other conditions, such as physical fatigue…. both 'physical' and 'neurocognitive' symptoms were often associated or interacting. Many highlighted the fatiguability of their neurocognitive or physical symptoms from either mental or physical effort."[31, p4]	Physical Cognitive Mental
"Physiological Fatigue is familiar to most persons, primarily resulting from exertion. It can also be caused by sleep loss or extended wakefulness, disrupted circadian rhythm or increased workload. In contrast, Pathological Fatigue or pathological exhaustion is more than tiredness and refers to physical and mental fatigue that may be caused by viral infection, bacterial infection, trauma, disease, over-work, over-training, epigenetic or genetic alteration that results in physical and mental fatigue that is not improved by bed rest and may be worsened by physical or mental activity"[76, p3]	Physical Mental
Participants' definitions summarised as—"frequently referring to "weakness" or instability during physical exertion in discussions of fatigue. Participants believed fatigue and brain fog to have a synergistic relationship (eg, worsening brain fog with increasing fatigue)"[32, p3] "Participants definitions of brain fog included the following descriptions: Head feeling fuzzy, foggy, or empty, Memory issues (eg, forgetfulness), Issues with speaking and/or word recall, Difficulty listening and/or language processing, Visual processing Inability to focus or multitask, Difficulty following steps in a sequence Losing time and/or "blanking" Difficulty planning or problem-solving, Mental fatigue Feeling inadequate, incompetent, or unproductive Stress and/or anxiety. Participants definitions of fatigue included the following descriptions: Mild tiredness, Extreme exhaustion, Disproportionate response to physical exertion/Lack of stamina, Light-headedness and/or Dizziness. Weakness. Lack of energy, Lack of stability, Sleep issues (eg, insomnia), Ineffectiveness of rest or sleep, Altered senses, Headache"[32, Supplementary 1]	Physical Mental
"Post exertional malaise is an abnormal physiological response to physical or cognitive stress that causes a severe combination of parainfluenza and neurological symptoms and, most importantly, overwhelming fatigue"[54, p8]	PESE
"Fatigue is defined as a debilitating feeling of mental and/or physical loss of energy and can be accompanied especially in the post-COVID-19 syndrome by a post exertional malaise"[34, p2]	Physical Mental PESE
"In general, fatigue describes the feelings of tiredness, lack of energy, low motivation, and difficulty in concentrating and can only be measured by self-report (Enoka et al. 2021). Fatigability, on the other hand, is a measure of physical or cognitive work capacity. Specifically, perceived fatigability subjectively estimates past or future work capacity whereas objective fatigability determines the magnitude of the change in a performance metric after completing a prescribed task"[35, p212] "Fatigue and perceived fatigability also depend on other factors, such as mood, stress, pain, depression, and anxiety"[35, p216]	Physical Cognitive
"Fatigue differs from sleepiness in that it encompasses a feeling of exhaustion and tiredness regardless of sleep quantity and quality. It is a nonspecific symptom that leads to a reduced overall capacity to accomplish routine tasks. This may involve the inability to initiate activity, inability to continue routine activities, or difficulty focusing and concentrating, with symptoms worsening after physical or mental exertion. This lack of energy affects physical, mental, and emotional states, altering overall quality of life"[77, p1]	Physical Mental
Fatigue is characterised by an overwhelming experience of weakness, exhaustion, and decreased capacity for physical or mental work which is disproportional to recent activity. Fatigue is a complex phenomenon at the interplay of central regulation (ie, homeostasis) and psychological factors like mood and motivation. In Post COVID syndrome, the experience of fatigue is frequently accompanied by muscle fatigue and fatiguability"[38, p11]	Physical Mental Central Psychological

Continued

Table 2 Continued

Definition quote. reference, page number	Dimension
Fatigue, defined as "a subjective, unpleasant symptom which incorporates total body feelings ranging from tiredness to exhaustion creating an unrelenting overall condition which interferes with individuals' ability to function to their normal capacity … Existing literature suggests that fatigue has several clinical presentations. A common distinction is made between physical fatigue (ie, difficulty performing physical activities) and mental fatigue (ie, difficulties concentrating and performing cognitive tasks)"[51, p2] "Fatigue is a complex and challenging symptom, as multiple factors can play a role in the initiation and maintenance of fatigue, as seen in other chronic diseases. It can present itself as mental fatigue, physical fatigue, or both"[51, p7]	Physical Mental
"Fatigue is defined as a feeling of tiredness and lack of energy, including physical and/or mental exertion that has an impact on everyday activities."[39, p1] "Fatigue may be categorized as peripheral or central. Peripheral fatigue is due to muscle and neuromuscular junction disorders and is characterized by muscle fatigability (ie, objective reduction in strength during effort, improving with rest). Central fatigue may be present in peripheral, autonomic, and central nervous system disorders, and involves a subjective feeling of exhaustion that is also present at rest. Interestingly, central fatigue usually also has a cognitive component (mental or cognitive fatigue). Cognitive fatigue refers to a decrease in mental effort in demanding cognitive tasks and may be as disabling as physical fatigue"[39, p2]	Physical Mental Peripheral Central Cognitive
"Fatigue is defined as a feeling of tiredness and lack of energy that has a negative impact on daily living activities. In post-COVID syndrome, fatigue is present at rest and is also usually triggered with effort, often manifesting with some delay… Fatigue usually has a physical and a cognitive dimension, which may have different pathophysiological mechanisms"[43, p2]	Physical Cognitive
"Fatigue is the expected result of over-exertion or lack of sleep and has been defined as an intense subjective sense of tiredness, energy depletion and weakness. The subjective nature of fatigue means that it is interpreted differently by different individuals. It manifests both physical (eg, muscle weakness) and cognitive (eg, reduced levels of concentration) symptoms and can range from tiredness to clinically relevant exhaustion"[61, p1]	Physical Cognitive Peripheral
"Chronic fatigue is a distressing, persistent feeling of weariness, tiredness, or exhaustion that is not alleviated by rest and is not proportional to recent activity levels..... post exertional malaise, is a worsening of symptoms, and reduction in function after physical, cognitive, or emotional activity that would not have caused a problem before illness"[9, p2] "post exertional malaise seems to be a common and significant challenge for the majority of this patient group and occurs alongside a reduced capacity to work, be physically active, and function both physically and socially"[9, p9]	PESE Physical Cognitive Emotional
"Fatigue represents the subjective sensation of the patient, while fatigability represents the change in performance, which can be measured. In addition, state fatigue represents the short-lasting, momentary condition often depicted by a visual analogue scale. Trait fatigue reflects a long-lasting condition, often regarding the last 4 weeks. It is most often captured in one of the many fatigue scales. Besides motor and cognitive fatigue, there is a third category termed emotional (or psychosocial) fatigue"[63, p2]	Physical Cognitive Emotional
"Participants described how fatigue can be caused by physical, mental, or emotional exertion"[48, p4]	Physical Cognitive Emotional

cognitive fatigue subscale. The most common measure was the MFIS (4/12 studies).

Mental fatigue

Mental fatigue was assessed separately to cognitive fatigue in 26/57 studies without explanation of the differences between the two concepts. Sixteen used validated multidimensional measures that included a mental fatigue subscale, the most common was the CFQ-11 (14/26 studies). One study only used the last six items of the 11 item CFQ-11 measure, which relate to mental fatigue, invalidating the scale. Nine studies utilised the FAS unidimensional measure, which considers physical fatigue but only provides a composite score of fatigue. One study used an unvalidated measure, in which questions related to physical fatigue were taken from the CIS fatigue subscale and replaced the word 'physical' in the question with 'mental'.

Psychosocial fatigue

Psychosocial fatigue was not clearly defined as a construct but was assessed in 5/57 studies. All used a multidimensional measure that included a psychosocial fatigue subscale, the most common of which was the MFIS (4/5 studies).

Emotional fatigue

Emotional fatigue was similarly not clearly defined as a construct but was assessed in 2/57 studies. Both used the Profile of Fatigue Related States, which is a validated multidimensional measure that provides an individual subscore of emotional distress.

PESE was assessed in 2/57 studies.

Observable measures

Across the five studies that used fatigability (non-self-report) measures, none quantified whether their fatigability measure was associated with any self-reported measure of fatigue.

DISCUSSION

This scoping review sought to summarise the definitions and measures of long COVID fatigue being used by researchers. The definitions and measures of fatigue used in long COVID research were reviewed and most

Figure 2 Twenty most commonly used words in fatigue definitions. The figure shows the most commonly For peer review only used terms to describe fatigue within the included studies.

contained methodological problems. There was a lack of consistency in the conceptualisation of fatigue and in the measures used to quantify fatigue in long COVID. This hinders comparisons across studies and impedes progress towards improved treatment and management.[16]

Only 37% of the reviewed studies provided an explicit definition of fatigue. Among the 21 definitions, 19 involved the interplay of multiple categories. This scoping review found that the categories of long COVID fatigue were referenced with little consistency; therefore, it is difficult to make any claims from the literature because it is not known how fatigue is being defined. The lack of precision in defining fatigue categories, as seen in mental and cognitive fatigue, hinders our understanding of the symptoms associated with each category as well as the ability to measure these constructs.

Although PESE is not one of the categories of fatigue put forward by Billones *et al*,[16] our review identified that it is frequently measured in long COVID fatigue research. PESE is not a type of fatigue itself but rather an exacerbation of multiple symptoms due to exertion, with fatigue often being one of the core symptoms.[82] Given that fatigue is such a core component of PESE and long while PESE is not a type of fatigue in itself, in the studies that we have found here, it is often being used in, it is often being used as a measure of fatigue. We have now included this detail within the manuscript and have highlighted that research needs to be careful in using these terms interchangeably.

The categories of fatigue identified through the definitions of fatigue used in long COVID research indicates that there are different dimensions of long COVID fatigue. However, these categories are not well defined across the available studies and there appears to be overlap between the identified categories, including the lack of distinction made between mental and cognitive fatigue. Therefore, there is not yet enough information to identify the specific dimensions of long COVID fatigue.

This scoping review also found that some studies defined fatigue as only an experience of symptoms (perceived fatigue only measurable via self-report) and others included elements of both perceived and performance fatigue (fatigue/fatigability) in their definition.

Table 3 Measures of fatigability

Measure	Phenomenon of interest	Outcome details	Studies	Aim of measure in the study
Twitch interpolation during maximal voluntary contraction	Central activation deficit (the ability of voluntary drive to fully activate a muscle)[87]	The increment in force produced by a supramaximal stimulus delivered to a muscle during a maximal voluntary contraction	Baker *et al*[53]	Quantify the change in central activation deficit of the biceps brachii muscle induced by a local fatiguing muscle contraction.
Twitch interpolation at rest	Force generating capacity of a muscle (independent of neural drive)[88]	The force produced by a supramaximal stimulus delivered to a muscle at rest.	Baker *et al*[53]	Quantify the change in force generating capacity of the biceps brachii muscle induced by a local fatiguing muscle contraction. Defined as a measure of peripheral fatigue.
Isokinetic fatigue test	The decline in physical work capacity over the duration of a physical task[89]	The decline in peak torque produced from the start to the end of a series of maximal effort isokinetic contractions.	Fietsam *et al*[35]	Quantify the ability to maintain physical work capacity of knee flexor and extensor muscles over time.
Fatigue Index Kliniken Schmieder	Altered movement patterns and variability representing motor fatigability.[90]	Movement pattern quantified using attractor attributes of the three-dimensional acceleration of the feet during walking.	Weich *et al*[63]	Quantify alterations in movement patterns and variability indicative of motor fatigability.
Muscle fatigue assessment	n/a	n/a	Zasadzka *et al*[69]	Unclear—used model LUNA Rehabilitation Robot

Moreover, some studies seemed to contradict themselves within their definition; for example, "post-COVID-19 fatigue was defined as the reduction in physical and/or mental performance …. Fatigue is a multidimensional symptom based on subjective perceptions."[29, p2] These terms being used interchangeably or together exacerbate the confusion surrounding long COVID.

Almost all studies in this scoping review focused on evaluating fatigue by self-report (89%). There is a core outcome set of recommended long COVID measures, which recommends three measures for long COVID fatigue: the FAS, FSS and Functional Assessment of Chronic Illness Therapy—Fatigue.[83] Of these, we found that 15 studies used at least one of these measures. The FSS was appropriately used in 7/11 studies, the FAS was used appropriately in 7/9 studies, and the FACIT was used appropriately in 1/4 studies. All three of the measures recommended from the core outcome set are unidimensional, providing an overall score of fatigue without individual scores for any dimension of fatigue. Within the core outcome set, there is also a Symptom Burden Questionnaire for long COVID, which considers burden of symptoms including memory, thinking and communication and does have a subscale which accounts for fatigue and the burden of symptoms.

Future studies should use recommended measures to allow comparisons across research. Where researchers want to evaluate multiple dimensions of fatigue, care should be taken when splitting validated unidimensional measures of fatigue into multiple dimensions, as this may invalidate its measurement properties. Therefore, until there is a bespoke/consensus long COVID fatigue measure that encompasses multiple fatigue-specific dimensions, researchers may wish to consider the multidimensional measures of fatigue outlined in this review.

Strengths and limitations

This review searched a number of databases to ensure that all relevant studies were identified. This included specialised databases that could have unique references where the topic of fatigue may be represented. However, this review only included English-language publications in the final analysis, possibly limiting conclusions as definitions and measures in different languages could have been omitted.

Implications for research

There is an urgent need to (a) define and measure long COVID fatigue more consistently and (b) identify the mechanisms involved in the experience of fatigue. Variability in how fatigue is defined and measured within the literature poses a substantial challenge to the synthesis of evidence and hinders our ability to develop effective, evidence-based interventions.

Our review highlights the critical importance of establishing consensus regarding the definition and measurement of long COVID fatigue in research. This consensus is being identified and developed in other clinical conditions, for example, rheumatology.[84] Future research should explore the concordance between research definitions and patient experiences to enhance intervention relevance and effectiveness in mitigating the impact of long COVID.

Implications for clinical practice

Without a unified understanding of long COVID fatigue, clinicians and policymakers cannot accurately interpret and compare study outcomes, this will hinder the development of effective and cost-effective interventions that depend on a consistent approach to obtaining evidence.

CONCLUSION

This review highlights inconsistency in definitions and measures of fatigue within long COVID research. Long COVID definitions are inconsistent, and at times contradictory including both symptom experience and performance decline within a description of fatigue. To develop our understanding of long COVID fatigue, definitions of long COVID fatigue need to be clear, with distinct separations made between the self-report experience and measures of fatigability that researchers decide to use within their research. Measures of fatigue or fatigability need to reflect and be consistent with the definition of fatigue.

Although not all studies used a multidimensional approach to long COVID fatigue, adopting a holistic approach considering all possible dimensions will facilitate better understanding. This review identified the current fatigue dimensions currently considered in long COVID research. If we believe long COVID fatigue has multiple dimensions, future research should map patient experiences onto these dimensions to ensure that aspects patients report as important are being accurately measured. Research has begun exploring patient perspectives on long COVID symptoms as demonstrated by the development of the core outcome set for long COVID measures.[83] This review also identified several qualitive studies that reported patient experiences and their personal definitions of fatigue. However, further research is needed to bridge the gap between the measures identified in this review and reported patient experiences.

Additionally, studies should examine which fatigue dimensions are most commonly reported in self-report and fatigability measures to understand which aspects of fatigue people with long COVID experience most intensely. This comprehensive mapping can help to better align research with patient experiences. Gaining a more comprehensive understanding of these dimensions could ultimately support clinicians in improving patient outcomes and enhancing the quality of life for individuals navigating this condition.

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