



Research Article

Assessment of pressure injury risk in intensive care using the COMHON index: An interrater reliability study

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ABSTRACT

Objectives: To assess the interrater reliability of the COMHON (level of Consciousness, Mobility, Haemodynamics, Oxygenation, Nutrition) Index pressure injury risk assessment tool.

Design: Interrater reliability was tested. Twenty-five intensive care patients were each assessed by five different nurse-raters from a pool of intensive care nurses who were available on the days of assessment. In total, 25 nurses participated.

Setting: Two general and one cardiovascular surgery intensive care units in Istanbul, Turkey.

Main outcome measures: Interrater reliability was analysed using intraclass correlations, and standard errors of measurement (SEM) were calculated for sum scores, risk level and item scores. Minimally detectable change (MDC) was also calculated for sum score. Consistency between paired raters was analysed using Pearson's Product Moment Correlation (r) for sum score and Spearman's rho (r_s) for ordinal variables.

Results: All assessments were completed in ≤ 5 min. Interrater reliability was very high [ICC (1,1) = 0.998 (95 % CI 0.996 – 0.999)] with a SEM of 0.14 and MDC of 0.39. Consistency between paired raters was strong for sum and item scores and risk levels (coefficients > 0.6). All scale items showed correlations of $> .3$ with the sum score.

Conclusion: The results demonstrate near-perfect interrater reliability. Further research into the psychometric properties of the COMHON Index and its impact on preventative intervention use is warranted.

Implications for clinical practice: Pressure injury risk assessment within intensive care should be setting-specific due to the unique risk factors inherent to the patient population, which are not considered by general pressure injury risk assessment tools.

An intensive care-specific pressure injury risk assessment tool was tested and demonstrated high reliability between intensive care nurses.

Further research is needed to understand how its use in practice affects preventative intervention implementation and, in turn, how it impacts pressure injury outcomes.

Introduction

Pressure injury (PI) is defined as 'localised damage to the skin and/or

underlying tissue, as a result of pressure or pressure in combination with shear', and is usually localised over bony prominences or is associated with a device or object (European Pressure Ulcer Advisory Panel et al.,

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2019). It is an ongoing challenge across acute health care settings, but intensive care unit (ICU) patients are at increased risk compared to other acute patients (Fulbrook et al., 2023b; Goodman et al., 2018). This is of concern, as PI can lead to complications for patients, including pain, discomfort and decreased quality of life (Burston et al., 2023), contribute to increases in healthcare costs and is a significant cause of morbidity and mortality (Agency for Healthcare Research and Quality, 2023). In a systematic review, Serrano et al. (2017) estimated mean ICU PI incidence of 18.3 % (range 3.3–39.3 %). Similarly, a 90-country international study found 16.2 % ICU-acquired PI prevalence, with 26.6 % overall ICU prevalence (Labeau et al., 2021). In United States hospitals, overall ICU PI prevalence was 14.3 % but only 5.9 % was hospital-acquired (Cox et al., 2022). In a sub-set analysis of the study by Labeau et al. (2021), Lin et al. (2022) reported overall and ICU-acquired PI prevalence in Chinese ICUs of 12.3 % and 4.3 %, respectively. In a similar sub-set analysis of Australian ICUs, the overall and ICU-acquired PI prevalence were 13.5 % and 9.7 %, respectively (Coyer et al., 2022) and, in an Australian statewide analysis, hospital-acquired ICU PI prevalence was 9.6 % (Fulbrook et al., 2023b). In contrast, in a national study, PI point-prevalence in Turkish ICUs was reported to be 43.2 %, with 65.1 % of ICU PIs being hospital-acquired (Baykara et al., 2023).

Pressure injury prevention begins with risk assessment, which is essential to inform subsequent preventative care (Lovegrove et al., 2023; Lovegrove, Miles & Fulbrook, 2018). To conduct an accurate risk assessment, ICU clinicians must have knowledge of patient risk factors. However, healthcare professionals need to more fully understand these risk factors (Sala et al., 2021) and no single factor can explain the occurrence of PI. Several factors have been identified in ICU including immobility, mechanical ventilation, vasopressor infusion, poor tissue perfusion and oxygenation, comorbidities, and ICU length of stay (Serrano et al., 2017). One structured approach to PI risk assessment, to aid the use of clinical judgement and knowledge of PI risk factors, is use of a PI risk assessment tool (Lovegrove et al., 2023). However, current risk assessment tools, such as the widely-used Braden Scale (Bergstrom et al., 1987), do not include risk factors specific to ICU patients (Fulbrook & Anderson, 2016; Lovegrove et al., 2020; Lovegrove et al., 2022). Furthermore, such tools mostly categorise ICU patients as “high risk” and may not take into account varying levels of risk for these patients (Richardson & Barrow, 2015). More recently, some ICU-specific risk assessment tools have emerged, including the EMINA (Fuentelsaz, 2001), RAPS-ICU (Wählin et al., 2021), EVARUCI (González-Ruiz et al., 2008), COMHON Index (Cobos Vargas et al., 2013) and CALCULATE (de Souza et al., 2023), in addition to the longer standing Jackson/Cubbin scale (Jackson, 1999).

Although a number of ICU-specific PI risk assessment scales have been described in the literature, the majority have only been tested in terms of predictive validity which is confounded where PI preventative measures follow risk assessment (Lovegrove et al., 2022) and it may not be feasible to develop a PI prediction model for ICU (Deschepper et al., 2021). Some authors, such as Han et al. (2024) have attempted to predict PI risk using computer-generated models incorporating a variety of risk factors. However, they fail to take into account the influence of nursing preventative interventions on the outcome variable. When a future occurrence of PI is the outcome of interest, it is argued that predictive validity of a PI risk assessment tool is an invalid psychometric property, as it would not be ethical to omit preventative interventions once it was known that a patient was at risk (Walsh & Dempsey, 2011). The implementation of preventative measures would confound the primary outcome measure. It is important to appreciate that risk assessment alone cannot prevent PI and therefore it cannot predict PI as an outcome; it is only preventative interventions that prevent PI (Anthony et al., 2008; Charalambous et al., 2018; Kring, 2007; Lovegrove, Fulbrook & Miles, 2018; 2020; Lovegrove, Miles & Fulbrook, 2018; Lovegrove et al., 2023). Risk assessment tools are used to assess the construct of *risk of possibly* developing a PI; not to predict PI as an outcome; as such, they are best regarded as screening tools to guide the

implementation of preventative measures. It is important to consider other psychometric properties, particularly interrater reliability given that multiple raters may assess individual patients using a tool (Fulbrook & Anderson, 2016; Lovegrove et al., 2022). Because PI risk assessment tools are used frequently in ICU nursing practice, a high level of agreement between users should be expected (Charalambous et al., 2018). If the initial risk assessment is inaccurate, it is likely that subsequent interventions will be inadequate or inappropriate.

The COMHON Index is an ICU-specific PI risk assessment tool which has demonstrated a range of promising psychometric properties, including interrater reliability (Cobos Vargas et al., 2013; Fulbrook & Anderson, 2016; Lovegrove et al., 2022). The scale was developed by Cobos Vargas et al. (2013) and comprises five subscales which are the basis of its title (COMHON): level of Consciousness (using the Richmond Agitation Sedation Scale; Sessler et al., 2002); Mobility; Haemodynamics; Oxygenation; and Nutrition. Each subscale has defined criteria and is scored from 1 to 4. The subscale (item) scores are summed to determine risk level (low 5–9; moderate 10–13; high 14–20). Initial evaluation of the COMHON Index in Spanish showed positive interrater reliability (kappa 0.89–0.93) and concurrent validity with the Braden (kappa 0.74–0.81) and Norton scales (kappa 0.72–0.73) (Cobos Vargas et al., 2013). Similarly, the English version demonstrated high interrater reliability (ICC (2,1) 0.90, 95 % CI 0.65–0.95) with nurses in an Australian ICU (Fulbrook & Anderson, 2016), and it has since been translated into Chinese Mandarin (Lovegrove et al., 2022).

In Turkey, where the prevalence of PI has been noted to be high, the Braden Scale is widely used (Baykara et al., 2023), including in studies with ICUs (Baykara et al., 2023; Inan & Öztunç, 2012; Kaşıkçı, et al., 2018; Sayan et al., 2020). Established ICU risk assessment methods have also included use of the Braden and Norton scales (Adibelli & Korkmaz, 2022). However, neither are ICU-specific. Indeed, a qualitative study in a Turkish ICU found that nurses believed these were not applicable because of the limitations of the included risk factors and outcome measures (Adibelli & Korkmaz, 2022). Subsequently nurses reported using heuristic risk assessment without structured tools, but their assessments were found to have significant limitations. Of consequence, inadequate risk assessment may have significant implications for the implementation of PI preventative interventions, with their use found to be suboptimal overall and in ICU (Adibelli & Korkmaz, 2022; Baykara et al., 2023). The limited availability of valid and reliable ICU-specific PI risk assessment tools in Turkey may contribute to this and highlights the need to address this issue.

Based on the international results supporting the use of the COMHON Index for ICU, the tool was identified as an appropriate means to address the lack of an ICU-specific PI risk assessment tool in Turkey. As such, it was formally translated from English (current version 2.1) into Turkish by the authors, following rigorous processes described by Lovegrove et al. (2022) (see Supplementary file 1). However, while the COMHON Index has demonstrated high reliability in other contexts (Cobos Vargas et al., 2013; Fulbrook & Anderson, 2016), psychometric testing of newly translated tools is a requirement prior to implementation into practice (Beaton et al., 2000; Cha et al., 2007; Lovegrove et al., 2022). This is important due to potential differences between settings and culture, however subtle, and to ensure reliability and validity is maintained. As noted, interrater reliability is of particular importance to PI risk assessment, which is generally performed by nurses. Therefore, the aim of this study was to test the interrater reliability of the translated COMHON Index with nurses in a Turkish ICU setting.

Methods

Design

An interrater reliability study was undertaken with the Turkish version of the COMHON Index in August 2023. Prior to interrater reliability testing, it was formally translated from English (current version

2.1) into Turkish by the authors. The current version (2.1) of the COMHON Index is available via the World Federation of Critical Care Nurses website (WFCCN, 2023) in Chinese, English and Spanish, with the Turkish version added following this study. Ethical approval was received from the Istanbul Medipol University Ethics Committee (ref: E-10840098-772.02-2875). Reporting was guided by the Guidelines for Reporting Reliability and Agreement Studies (GRRAS; Kottner et al., 2011; Supplementary file 2).

Setting

The setting for this study was two general ICUs (48 beds) and one cardiovascular surgery ICU (17 beds) in a university hospital in Istanbul, Turkey. Nurses working within the ICUs receive PI training during orientation and then every two-years, which includes education on PI definitions, prevention and wound care. Educational and procedural documents for PI and prevention are readily available to nurses in the hospital's quality documentation system, and posters are available on the unit displaying PI stages. Case discussions on patients with or developing PI are held during bedside rounds with short education sessions given on up-to-date information, and regular in-service training is undertaken on topics including PI prevention. There is also an online unit discussion board to discuss wound care practices and share current materials and information.

In standard practice, the Braden Scale is completed twice daily by ICU nurses to assess PI risk. Skin assessments and PI are documented on a patient form once daily, with the form including skin characteristics, patient positioning, use of skin cleansers and support materials, use of equipment which may cause PI, and PI presence and characteristics. ICU PI development rates are regularly reported to the hospital quality unit, monitored and audited.

Sample

Nurses with at least six months' ICU experience and were available at the time of the study were eligible for inclusion as raters. The nurse-raters completed assessments on a convenience sample of adult patients (≥ 18) admitted to ICU for at least 24 h. Patients were recruited until the required sample size was met.

The tables of Walter et al. (1998) were used to calculate patient sample size, which required an input of number of raters, and minimum acceptable and top anticipated intraclass correlations (ICC) for inter-rater reliability. For each patient, a sample of five nurse-raters was selected based on previous research (Fulbrook & Anderson, 2016), with nurses able to differ between patients (Kottner & Dassen, 2010; Kottner et al., 2014). Minimum acceptable ICC was set at 0.60 as suggested by Shoukri et al. (2004), and a top anticipated ICC of 0.90 for the COMHON Index was set based on previous interrater reliability testing (Fulbrook & Anderson, 2016). These inputs resulted in a required patient sample size of 19.9 ($\alpha = 0.05$, power = 80 %). To account for data loss or attrition, a target sample of 25 patients was set.

Procedure

On the days of data collection, patients were assessed for eligibility by one of the researchers. Concurrently, the researcher identified eligible nurses from those present based on availability, informed them of the study and obtained their verbal consent. Prior to assessments, nurse-raters were informed of the purpose of the COMHON and its contents; no additional PI training was provided for the study.

In ICU patients who were conscious, the patient was informed about the research and invited to consent, and in unconscious patients, consent was obtained via the legal representative (family member). Following consent, five different nurse-raters assessed each individual patient using the COMHON Index independently and within one hour of each other (to ensure that there was no change in the patients' condition) at a

mutually agreed time. During assessments the nurses were asked not to discuss their results with each other.

Data analysis

Data were entered into Microsoft Excel™ and a statistical software package (IBM SPSS™ version 28) for analysis. Descriptive statistics (counts and proportions for categorical data; means, standard deviations and ranges for continuous data) were used to summarise the nurse-rater sample and overall patient assessment scoring and risk levels. Statistical significance was considered $p < 0.05$.

For repeated measurements on a scale, ICC is the most appropriate method to assess reliability (de Vet et al., 2006; Streiner & Kottner, 2014). It takes both exact agreements and the extent of disagreements into account (Kottner & Dassen, 2010). In this study, we calculated ICC to assess interrater reliability of the COMHON Index sum score, risk level, and item scores, to assess whether the judges (nurse-raters) were interchangeable and to generalise to other raters in the population (Shrout & Fleiss, 1979). A one-way random effects model [ICC (1,1)] was used to explore absolute agreement between nurse-raters, as this model is more aligned with clinical practice variations. This model is used when each subject is rated by a different set of judges (nurse-raters), selected randomly from a population of judges (Shrout & Fleiss, 1979), and where a single rater (individual nurse) would normally undertake the measurement (Koo & Li, 2016). In this study, the number of judges in each set of nurse-raters was $k = 5$.

Following the approach of Fulbrook and Anderson (2016), standard errors of measurement (SEM) were calculated for sum score, risk level, and item scores; and minimally detectable change (MDC) was calculated for sum score. The SEM should not be greater than MDC, which is a measure of the minimally important change (MIC) and, in the context of PI risk, an MIC is a change in score that would move an individual up or down a risk level (Fulbrook & Anderson, 2016). With the COMHON Index, a change in the score by 1 could be sufficient to change the risk level, thus an MDC of 1 or higher would arguably represent a MIC; although it would not always result in a risk level change. The MDC value answers the question of whether a measure is able to detect changes as small as the MIC (de Vet et al., 2006).

The direct calculation of SEM requires the determination of standard deviation (SD) from a large number of scores from an individual (Weir, 2005). However, as this was not available, SEM was estimated using the following formula (Tighe et al., 2010; Weir, 2005), where SD was determined as the SD of the scores from all the risk assessments ($n = 125$): $SEM = SD \times \sqrt{1 - ICC}$

MDC was calculated using the following formula (Beckerman et al., 2001; Weir, 2005):

$$MDC = 1.96 \times \sqrt{2} \times SEM.$$

Consistency between paired raters was analysed using Pearson's Product Moment Correlation (r) for sum score and Spearman's rho (r_s) for ordinal variables (risk level, item scores). Discriminatory power of the COMHON Index was investigated by examination of its corrected item-total correlation values.

Results

Sample

Twenty-five nurse-raters (mean age 26 years, SD 4; 73 % female) with mean 44 months' (range 8–150) nursing experience and 39 months' (range 6–144) ICU experience participated. Each patient participant ($n = 25$) was assessed by five nurse-raters. The mean COMHON Index score for all assessments ($n = 125$) was 12.86 (SD 3.13, range 6–19). Most assessments judged the patient to be at high risk (57.6 %, $n = 72$) with around a quarter judged to be at moderate risk (26.4 %, $n = 33$), and the remainder at low risk (16.0 %, $n = 20$).

Reliability

Interrater reliability of the COMHON Index sum score was found to be very high [ICC (1,1) = 0.998 (95 % CI 0.996–0.999)] with a small SEM of 0.14 and an MDC of 0.39 with risk level and item score ICCs similarly high (see Table 1). When correlations between paired raters were examined, the sum score, risk level, and item scores all observed coefficients greater than 0.6, indicating strong associations, with most associations being near perfect (see Table 2).

All inter-item correlation values were positive, indicating they were all measuring the same construct. Discriminatory power was supported by examination of corrected item-total correlation values, which were all above 0.3 (range 0.391–0.727). The lowest value was found for the *Haemodynamics* item, however single item deletions did not result in significant changes to Cronbach's alpha. A correlation matrix with values derived from Spearman's ρ was constructed (see Table 3). Most item pairs were moderately to strongly correlated ($r_s > 0.6$). One item (*Mobility*) was moderately correlated with risk level ($r_s = 0.563$, $p < .001$) whereas the remainder were all strongly correlated.

Discussion

The Turkish COMHON Index has demonstrated a high level of reliability, which was near perfect, in the intended setting. This is consistent with the English version, which had high interrater reliability (ICC (2,1) 0.90, 95 % CI 0.65–0.95) in an Australian ICU compared to three well-established scales (Braden, Norton, Waterlow) (Fulbrook & Anderson, 2016). The Turkish COMHON Index was translated from the English version following rigorous processes (Lovegrove et al., 2022), and indicates such an approach has maintained equivalence across the tool versions. However, further testing of its psychometric properties is recommended, and is important following translation, to ensure reliability and validity in a new context (Beaton et al., 2000; Cha et al., 2007; Lovegrove et al., 2022). In ICU, there are only a few other studies that have investigated interrater reliability of PI risk assessment tools using ICC, which is considered to be the most appropriate method to assess interrater reliability of a continuous score (Kottner et al., 2011). In an earlier two-ICU study, Kottner and Dassen (2010) reported ICCs of 0.72 and 0.84 for the Braden Scale, and a later Chinese study using the Braden, Norton, and Waterlow tools reported ICCs of 0.96, 0.96, and 0.98, respectively in a small subset of three ICU patients (Wang et al., 2015). More recently, an ICU study using the Braden Scale reported moderate values of ICC (range 0.48–0.75) in four groups of patients, with borderline SEM values (Veiga et al., 2022).

In Turkish ICUs, one other study has examined a PI risk assessment tool with ICC in ICU. Günes and Efteli (2015) assessed interrater reliability of a Turkish version of the Risk Assessment Pressure Sore (RAPS) scale in 30 patients with two raters, reporting a high ICC of 0.92 (95 % CI 0.82–0.96) and internal consistency (Cronbach's alpha 0.81). However, the RAPS scale had not yet been modified specifically for ICU (Wählin et al., 2021). Meanwhile, Adibelli and Korkmaz (2019) compared the reliability and validity of the Braden and Jackson/Cubbin scales,

Table 2

Correlations between paired raters ($n = 25$).

Item (score range)	Correlation range r
Sum score (5–20)	0.981–0.993
Risk level (1–3)	0.949–1
Conscious level (1–4)	0.950–1
Mobility (1–4)	0.634–0.909
Haemodynamics (1–4)	0.892–1
Oxygenation (1–4)	0.993–1
Nutrition (1–4)	1

*Values for all pairs; all values significant at $p < .001$; r = Pearson's Product Moment Correlation.

investigating internal consistency and reporting Cronbach's alpha of 0.85 and 0.78, respectively. However, while the Jackson/Cubbin is ICU-specific, the use of internal consistency as a psychometric property is not appropriate for PI risk assessment tools (Kottner & Streiner, 2010; Lovegrove et al., 2022), and interrater reliability was not tested. Provision of the Turkish COMHON Index, which has demonstrated high interrater reliability and is freely available for use (WFCCN, 2023), is a significant contribution to ICU practice in Turkey where such an ICU-specific tool was previously lacking.

Several studies have reported use of the COMHON Index. In Spain, Arroyo-López et al. (2022) investigated use of a COMHON Index moving average score to assess PI risk, finding that a cut-off score of ≥ 11 was a significant predictor (odds ratio 1.39, 95 % CI 1.20–1.62). In contrast, a Thai study reported a cut-off score of ≥ 14 in a small sample (Theeranunt et al., 2021). However, as noted above, it is not appropriate to evaluate predictive validity of a risk assessment tool without consideration of preventive intervention implementation. Indeed, PI preventative intervention implementation must follow and be guided by PI risk assessment, otherwise it is redundant (Lovegrove et al., 2023; Lovegrove, Miles & Fulbrook, 2018). It was in this light that the COMHON Index was used as the basis of an international Delphi study to determine international consensus for interventions to prevent PI, according to risk level, in ICU patients (Lovegrove et al., 2020). Subsequently, Cobos-Vargas et al. (2023) used the international consensus paper to analyse the degree of compliance with the recommended preventive measures, reporting variable degrees of compliance with corresponding COMHON Index risk levels. Use of a reliable ICU-specific PI risk assessment tool has the potential to better guide PI preventative intervention use in Turkey, which has previously been suboptimal (Adibelli & Korkmaz, 2022; Baykara et al., 2023). Further research examining use of the Turkish COMHON Index and its impact on PI preventative intervention implementation is required.

It is important to note that whilst the COMHON Index score identifies PI risk, it does not assess risk associated with medical devices. Critically ill patients are particularly vulnerable to medical device-related (MDR) PI due to the necessary use of multiple devices (Coyer et al., 2017) and MDRPIs occur frequently in ICU, most often caused by endotracheal tubes resulting in mucous membrane PIs (Fulbrook et al., 2023a). However, this is the case across all PI risk assessment tools, and is also an area for further research.

Limitations

The nurse-raters in this study were experienced ICU nurses from a single hospital and may not be representative of the general population of ICU nurses. As well, all nurse-raters were employed within the same ICUs where initial testing of the Turkish version of the COMHON Index occurred. To some extent their investment in the scale development may have influenced their diligence in its testing, leading to higher interrater reliability scores than might ordinarily be expected in everyday practice.

Table 1

Inter-rater reliability [ICC (1,1)] and agreement of sum score, risk category and item scores ($k = 5$).

Item (score range)	ICC (95 % CI)	SEM (MDC)
Sum score (5–20)	0.998 (0.996–0.999)	0.14 (0.39)
Risk level (1–3)	0.996 (0.993–0.998)	0.05
Conscious level (1–4)	0.994 (0.990–0.997)	0.09
Mobility (1–4)	0.934 (0.882–0.967)	0.44
Haemodynamics (1–4)	0.991 (0.984–0.995)	0.09
Oxygenation (1–4)	0.996 (0.993–0.998)	0.06
Nutrition (1–4)	1	0

ICC = intraclass correlation; k = number of rates; MDC = minimally detectable change; SEM = standard errors of measurement.

Table 3
Item correlations ($n = 125$).

Item	Correlation (r_s)*				
	Risk level	Conscious level	Mobility	Haemodynamics	Oxygenation
Conscious level	0.810	–	–	–	–
Mobility	0.563	0.399	–	–	–
Haemodynamics	0.627	0.330	0.388	–	–
Oxygenation	0.750	0.736	0.566	0.274	–
Nutrition	0.697	0.539	0.692	0.464	0.725

*All values significant $p < .001$; r_s = Spearman's rho.

Conclusions

The Turkish version of the COMHON Index demonstrated near perfect interrater reliability. In terms of precision, there was a very small MDC and instrument measurement error. The ICC found in this study was higher than that found in previous testing of the English version and, based on other studies that have used ICC to assess reliability in ICU settings, outperforms the Braden Scale. Further testing of the psychometric properties of the COMHON Index is warranted, including its convergent validity with other risk assessment scales. As well, further research is needed to understand how its use in practice affects preventative intervention implementation and, in turn, how it impacts PI outcomes.

Ethical statement

Participation in the study required oral and written information and signed informed consent. Formal ethics approval was received from the Istanbul Medipol University Ethics Committee (reference: E-10840098–772.02–2875) before data collection.

CRedit authorship contribution statement

Yasemin Uslu: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Paul Fulbrook:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Esra Eren:** Writing – review & editing, Resources, Project administration, Methodology, Data curation, Conceptualization. **Josephine Lovegrove:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Angel Cobos-Vargas:** Writing – review & editing, Conceptualization. **Manuel Colmenero:** Writing – review & editing, Conceptualization.

Declaration of competing interest

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

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Appendix A. Supplementary data

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